WYOMING GAME AND FISH DEPARTMENT

FISH DIVISION

ADMINISTRATIVE REPORT

Title: Trout Creek, Tributary to North Fork Shoshone River, Instream Flow Studies

Project: AW-CY-IF5-511

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EXECUTIVE SUMMARY

A two-mile segment of Trout Creek in the North Fork Shoshone River basin was selected for an instream flow water right because the headwaters have high purity re-introduced Yellowstone cutthroat trout (YSC; *Oncorhynchus clarki bouvieri*) and the lower reaches have an important spawning and nursery function for YSC and rainbow trout from the North Fork Shoshone River and Buffalo Bill Reservoir. This report provides flow recommendations developed from studies conducted in 2004. Physical Habitat Simulation (PHABSIM) was used to develop instream flow recommendations for maintaining YSC spawning habitat during spring runoff. Riffle hydraulic characteristics under the Habitat Retention approach were examined to ensure that flow recommendations from other methods did not impede fish movement. The Habitat Quality Index (HQI) model was used to assess stream flow versus adult trout habitat quality relationships in the summer. During the winter months, October through April, natural winter flows were recommended to maintain all life stages. The 20% monthly exceedance, based on hydrologic estimates from HabiTech (2004), was selected to represent natural winter flow. Finally, a dynamic hydrograph model was used to quantify flow needs for maintenance of channel geomorphology.

Two miles of important YSC habitat on Forest Service land will be directly protected if the instream flow segment and recommendations identified in this report advance to permit status. In addition, over 100 headwater stream miles will be indirectly protected. Recommended flows range from a low of 7.0 cfs in January and February to 26 cfs in April through June (Table 1). Additional channel maintenance flow recommendations for long-term habitat maintenance are presented in Appendix 1.

Table 1. Instream flow recommendations to maintain trout habitat in the Trout Creek instream flow segment.

Monthly Flow Recommendations (cfs)												
Oct	Nov	Dec	Jan	Feb	Mar	Apr*	May*	Jun*	Jul* 1 - 15	Jul 16 - 31	Aug	Sep
15	10	7.7	7.0	7.0	7.1	26	26	26	26	18	18	18

* Channel maintenance flow recommendations for the spring runoff period are defined in Appendix 1.

INTRODUCTION

Overall Approach

This report was compiled around a framework recognizing important components of an aquatic ecosystem and their relationship to stream flow. The results and analyses represent a continuing evolution from early Wyoming Game and Fish Department (WGFD) instream flow reports, which focused solely on sport fish species and maintenance-level instream flow recommendations, toward a focus consistent with contemporary understanding of stream ecosystems and their management. In conducting and reporting instream flow studies, the WGFD is working toward recommendations of the Instream Flow Council (IFC), an organization of state and provincial fishery and wildlife management agencies (Annear et al. 2004). These recommendations include consideration of three policy components (legal, institutional, and public involvement) and five riverine components (hydrology, geomorphology, biology, water quality and connectivity; Annear et al. 2004). Sections and headings throughout this report were selected to generally reflect those components. By using the eight components as a guide, we strive to develop instream flow recommendations that work within Wyoming's legal and institutional environment to preserve important aquatic resources for public benefit.

Legal and Institutional Background

The Wyoming Game and Fish Department manages fish and wildlife resources under Title 23 of Wyoming statutes (W.S.). The WGFD was created and placed under the direction and supervision of a Commission in W.S. 23-1-401 and the responsibilities of the Commission and the Department are defined in W.S. 23-1-103. In these and associated statutes, the Department is charged with providing " . . .an adequate and flexible system for the control, propagation, management, protection and regulation of all Wyoming wildlife." The WGFD mission statement is: "Conserving Wildlife - Serving People" while the Fish Division mission statement details a stewardship role toward aquatic resources and the people who enjoy them. In a 2005 policy statement, the Commission formally assigned responsibilities for implementing instream flow water rights to the WGFD and specified procedures for notifying the Commission of instream flow filing activities.

The instream flow law, W.S. 41-3-1001-1014, was passed in 1986 and establishes that "unappropriated water flowing in any stream or drainage in Wyoming may be appropriated for instream flows to maintain or improve existing fisheries and declared a beneficial use..." The statute directs that the Game and Fish Commission is responsible for determining streamflows that will "maintain or improve" important fisheries. The WGFD fulfills this function under the general policy oversight of the Commission. An application for an instream flow water right is signed and held by the Wyoming Water Development Commission (WWDC) on behalf of the state should the water right be approved by the State Engineer. The priority date for the instream flow water right is the day the application is received by the State Engineer.

There are alternative interpretations of the word "fishery" found in the instream flow legislation. From a natural resource perspective, a fishery includes the diverse fish habitats of the stream channel, riparian zone and floodplain as well as the processes of sediment flux and riparian vegetation development that sustain those habitats (Annear et al. 2004). To maintain the existing dynamic character of the entire fishery, instream flows must maintain the stream channel and its functional linkages to the riparian corridor and floodplain to perpetuate habitat structure and ecological function. The State Engineer has concluded that such channel maintenance flows are not consistent with the legislative intent of the instream flow statute. Therefore, until the institutional climate and interpretation of state water law changes, channel maintenance flow recommendations are not included on instream flow applications.

Channel maintenance flow requirements are presented in Appendix 1 of this report, should opportunities arise in the future to secure instream flow water rights for this important component of the hydrograph.

Through March 2006, the WGFD has forwarded 97 instream flow water right applications to the WWDC for submission, while the State Engineer has permitted 52, and the Board of Control has adjudicated four. Recently, we have focused on small headwater streams supporting native cutthroat trout. For example, studies were conducted from 1998 to 2003 on thirteen Greybull River tributary stream segments containing YSC (*Oncorhynchus clarki bouvieri;* Dey and Annear 2004). This document continues that focus by presenting study results and instream flow recommendations for a YSC stream in the North Fork Shoshone River drainage.

Yellowstone Cutthroat Trout

Trout Creek was identified as an important fishery for its role in sustaining YSC. The Yellowstone cutthroat trout was petitioned for listing under the Endangered Species Act in 1998. In February 2001, the Fish and Wildlife Service (FWS) completed a 90-day petition review finding that the petitioners failed to present adequate information indicating that listing may be warranted. In January 2004, a suit was brought against the FWS alleging that this finding did not follow the tenets of the review process. In December 2004, the 9th Circuit Court overturned the FWS 90-day ruling on the basis that proper procedures were not followed and ordered the FWS to conduct a 12-month review, due February 14, 2006. Against this backdrop, the WGFD continues management efforts to protect and expand YSC populations (WGFD 2005). Securing adequate instream flow water rights is a prominent component of these efforts. Instream flow protection will help ensure the future of YSC in Wyoming by protecting existing base flow conditions against future consumptive and diversionary demands (which are presently unknown). Additional water rights for channel maintenance are still needed to ensure long-term habitat and fishery persistence.

Yellowstone cutthroat trout historically occupied Wyoming waters in the Snake River and Yellowstone River drainages, including the tributary Wind/Bighorn and Tongue River drainages (Behnke 1992, May et al. 2003). More recent distributional information is summarized in May (1996), Kruse et al. (1997), Dufek et al. (1999), and May et al. (2003). In 2001, fisheries experts from Wyoming, Montana, and Idaho compiled information on YSC populations, including genetic status and population demographics (May et al. 2003). This project identified conservation populations and assessed the relative extinction risk among populations. Of the extant populations, those in the Greybull River and tributary Wood River contain genetically pure populations that span a large geographic area (Kruse et al. 2000) and hence were targeted first for instream flow studies during 1997 through 2003.

Trout Creek was identified as an instream flow prospect following discussions with the Cody Regional Fisheries Crew and Aquatic Habitat Biologist. Trout Creek stood out during efforts to rank basins and streams according to miles of stream habitat occupied by genetically pure YSC (Dey and Annear *in preparation*). The headwaters were stocked with genetically pure YSC in 1995, above a barrier to upstream movement, thereby providing many new miles of occupied habitat. In addition, a substantial spawning run of cutthroat trout, rainbow trout (RBT; *Oncorhynchus mykiss*), and cutthroat X rainbow trout hybrids from Buffalo Bill Reservoir occurs in lower Trout Creek. An instream flow segment in lower Trout Creek would serve a dual purpose: directly protect habitat used by large, spawning trout from Buffalo Bill Reservoir and indirectly protect restored headwater populations of genetically desirable YSC. Indirect protection occurs by virtue of the fact that any new water development upstream of the instream flow segment must pass enough water to meet the senior instream flow water right. Depending on the quantity of the instream flow water right, little to no consumptive uses may be possible in the headwaters and still satisfy the downstream instream flow water right.

Public Participation

The public has several opportunities to be involved in the process of identifying instream flow segments or commenting on instream flow applications. First, people can make us aware at any time of important fisheries to consider for instream flow filings. We develop annual work schedules and five-year plans that are available for public review and comment. The State Engineer is required to conduct a public hearing on the proposed instream flow water right to gather information for consideration before issuing a decision on the instream flow water right application. Prior to this hearing, the WGFD often conducts an informal information meeting to distribute information about the instream flow study (i.e., this report) and answer questions. Additional presentations to community or special interest groups also provide opportunity for discussion.

Meeting with landowners adjacent to or immediately downstream from instream flow segments is vital for sharing information about aquatic resources and the instream flow study, and sometimes for securing access to conduct the instream flow study. While most instream flow segments are delineated on public land where unappropriated water remains, landowners are given the opportunity to consider an instream flow segment on streams crossing their property. For Trout Creek, we met with the owner of Trout Creek Ranch. While not interested in an instream flow segment crossing Trout Creek Ranch property, the owner provided access which allowed us to conduct studies on the Shoshone National Forest for an instream flow segment on public land and ending at the Forest Service boundary (see below).

Objectives

The objectives of this study were to 1) quantify year-round instream flow levels that maintain base-level Yellowstone cutthroat trout habitat, 2) provide the basis for filing an instream flow water right application to maintain hydraulic conditions for YSC, and 3) identify channel maintenance flows that maintain long-term trout habitat and related physical and biological processes. The audience for this report is broad and includes the State Engineer and staff, the Water Development Commission and staff, aquatic habitat and fishery managers, interest groups like Trout Unlimited and anyone interested in instream flow water rights in general or an instream flow water right on Trout Creek, in particular.

STUDY AREA

Trout Creek Basin Description

Trout Creek basin (hydrologic unit code 100800120304) area is 48 square miles and is about 6% of the total North Fork Shoshone River basin area upstream from the mouth of Trout Creek (Figure 1). The North Fork Shoshone River basin is the number one WGFD aquatic habitat priority in the Cody Region. Highway 14-16-20 parallels the North Fork Shoshone River for much of its length and provides both a heavily traveled route for tourists heading to Yellowstone National Park and an artery for use of the Shoshone National Forest. Recreational uses in the drainage include fishing, boating, camping, hunting, and horseback riding and packing.

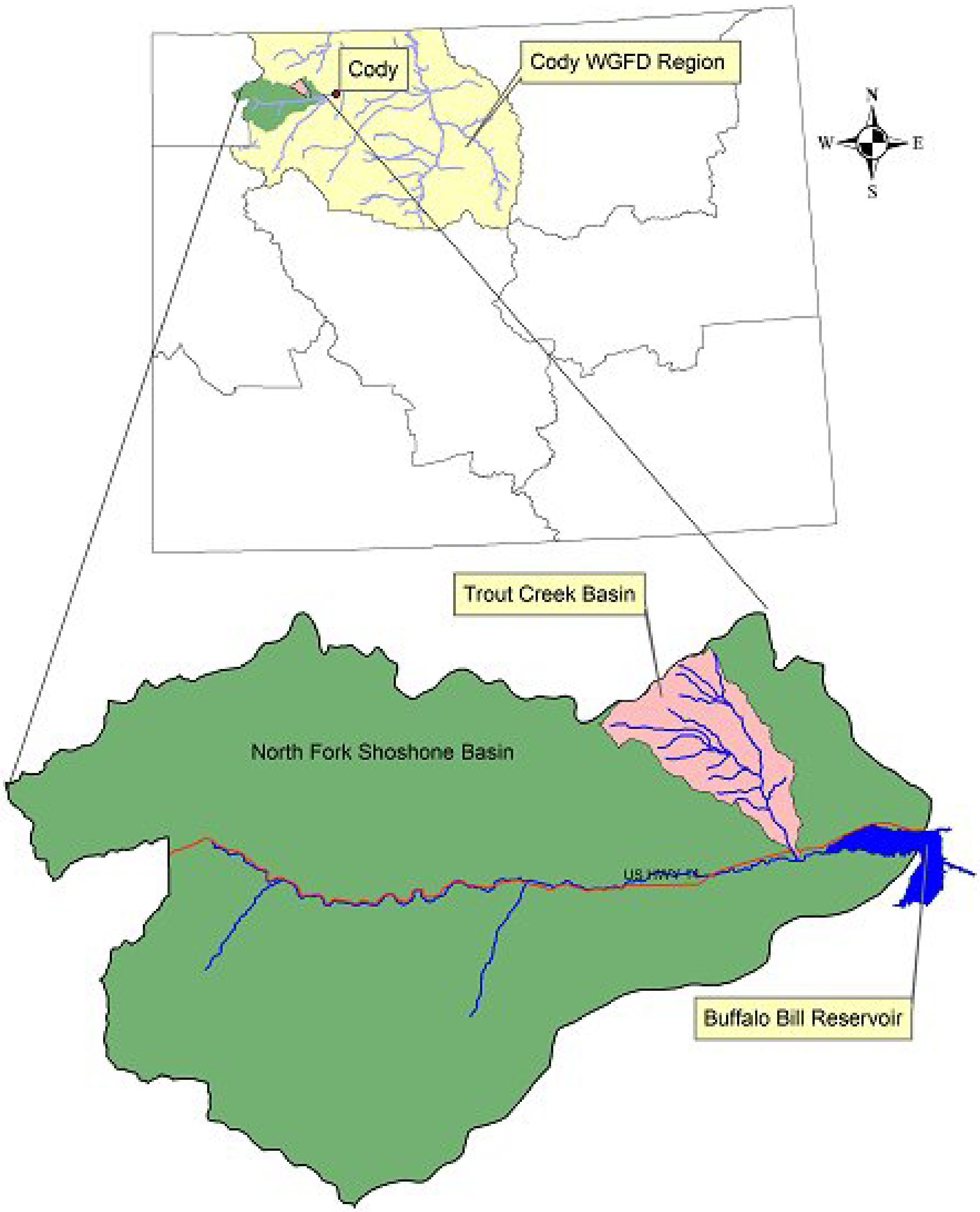

Figure 1. Location of Trout Creek basin, WY (hydrologic unit code 100800120304).

Trout Creek enters the North Fork Shoshone River just over two miles upstream from the high water zone of Buffalo Bill Reservoir, about 16 miles west of Cody, Wyoming (Figure 1). Basin elevation ranges from 5,413 feet at the mouth of Trout Creek to 12,244 feet atop Trout Peak. The basin's primary aspect is south facing. Annual precipitation at nearby Buffalo Bill Dam averaged 11 inches over the period 1948 – 2005, but precipitation is substantially greater at higher elevations in Trout Creek basin.

Geology

Trout Creek and its tributaries are high-elevation Absaroka Mountain streams with steep channel slopes and unstable substrates. These characteristics derive from the geologically young nature of the Absaroka Mountain Range, which are remnants of a broad volcanic plateau that continues to erode as regional uplift occurs (Lageson and Spearing 1988). Igneous rock of the Wapiti Formation underlies much of the Trout Creek basin. Other bedrock units include glacial and landslide deposits and a small proportion of Madison Limestone. Annual precipitation is primarily snow, which leads to large fluctuations in annual discharge, including torrential spring flows during snowmelt runoff (Curtis and Grimes 2004). High snowmelt runoff easily moves erodible volcanic material resulting in stream channels that shift regularly, transport a lot of sediment and offer limited fish habitat. Earthen slumps are common and influence stream channel patterns by sometimes directly blocking or altering stream flow and providing large sediment supplies for eventual transport. Valley vegetation communities respond to mass wasting events with colonizing species, often aspen, establishing on denuded hill slopes.

From Rosgen's (1996) level I geomorphic classification, the V-shaped Trout Creek valley conforms to valley types I and II. Stream channels throughout the Trout Creek basin would be primarily classified as "A" and "B" from inspection of 1:24,000 scale topographic maps. The stream channel at the lower end of the instream flow segment (segment location is described in a later section) is a B3 channel type (Table 2), reflecting a cobble bed and moderate entrenchment, slope and width-depth ratios. The floodplain is narrow, ranging from about 20 to 60 feet. Additional channel measurements are provided in Appendix 3 for reference.

Table 2. Stream channel measurements at the Trout Creek study site.

Channel Feature	Value
Mean riffle bankfull width (ft)	20.3
Mean depth (ft)	0.84
Cross section area (ft^2)	16.6
Entrenchment ratio	1.52
*D50 (mm)	91
Slope (ft/ft)	0.0219
Sinuosity	1.74
Stream Type	B3

* D50 is the median particle size on a cumulative frequency plot.

A B3 channel is very stable in pattern and profile (Rosgen 1996). Sediment is transported through but relatively little net removal or deposition occurs. Also, periodic pulses of high flow approximating a natural hydrograph remove fine organic sediment accumulations that might otherwise change ecosystem function under a reduced flow regime. For example, accumulated organic sediment might impair oxygenation of trout eggs and ultimately reduce or limit trout abundance. Periodic bankfull and higher flows to maintain floodplain features are developed in Appendix 1.

Shoshone Basin Hydrology

No gage records exist for Trout Creek but nearby gages on the North Fork Shoshone River and South Fork Shoshone River illustrate flow patterns (Figure 2). The nearest currently operating USGS gage is on the North Fork Shoshone River at Wapiti, 4.2 miles upstream from the mouth of Trout Creek (6279940). This gage began operating in October 1989. A gage (6280000) was also operated for 16 years, ending in September 1989, on the North Fork Shoshone River below Trout Creek. Irrigation diversions for about 2,700 acres and 1,500 acres occur upstream of gage 6280000 and 6279940, respectively. The South Fork Shoshone River gage (6280300) is about 24 miles away from the Trout

Creek mouth and has operated the longest (47 years) from 1957 to 2004. Annual flow exceedance curves from the three gages are very similar indicating similar hydrology (Figure 2; HabiTech 2004).

Stream flows at these gages are typical of snowmelt runoff streams with flow peaks occurring between May 14 and July 22 (median North Fork Shoshone River date is June 9). Annual flow minima occur in winter, usually January or February (Figure 3). While a wide variety of statistics can describe hydrology, annual stream flow variability (ASFV) and critical period stream flow (CPSF) from Binns (1979) are listed in Table 2 because these parameters are calculated for Trout Creek later in this report. Annual stream flow variability is the ratio of the instantaneous annual peak flow to the annual low flow and averages a moderate 77% at the North Fork Shoshone River gages (Table 3). Suitability for trout expressed in a habitat score would be lower if ASFV were above 100% (Binns 1982). Conversely, habitat suitability would be considered higher if the ASFV were below 40%. The CPSF is the average August 1 through September 15 flow expressed as a percent of average daily flow and averages 59%. This CPSF value represents relatively high flow levels in late summer and indicates trout habitat is likely to be high during this time of year compared to streams with low summer flows. Values of CPSF less than 55% would result in a lower trout habitat score.

Table 3. Hydrologic statistics from the North Fork Shoshone gage stations.

	Annual Stream Flow Variability (ASFV; annual peak flow / lowest daily flow	Critical Period Stream Flow (CPSF; Aug 1 – Sep 15 average flow / average annual flow
Mean (%)	77	59
Range (%)	25 – 182	16 – 93
n (years)	30	28

To further illustrate basin hydrology, five annual hydrographs from the North Fork Shoshone River are plotted in Figure 3. Spanning the range from wet to dry years, the hydrographs show that annual low flows occur in the winter and at a consistent level regardless of runoff volume. Most years have multiple high flow events occurring between mid-May and mid-July. Peak flow magnitudes differ markedly as expected for a comparison of wet to dry years. Also noteworthy, since cutthroat trout are spring spawners, is flows often begin to rise in April and sometimes even March, which could provide migration cues to Buffalo Bill Reservoir resident trout. Base flow recession occurs throughout summer with near base flow levels attained by October.

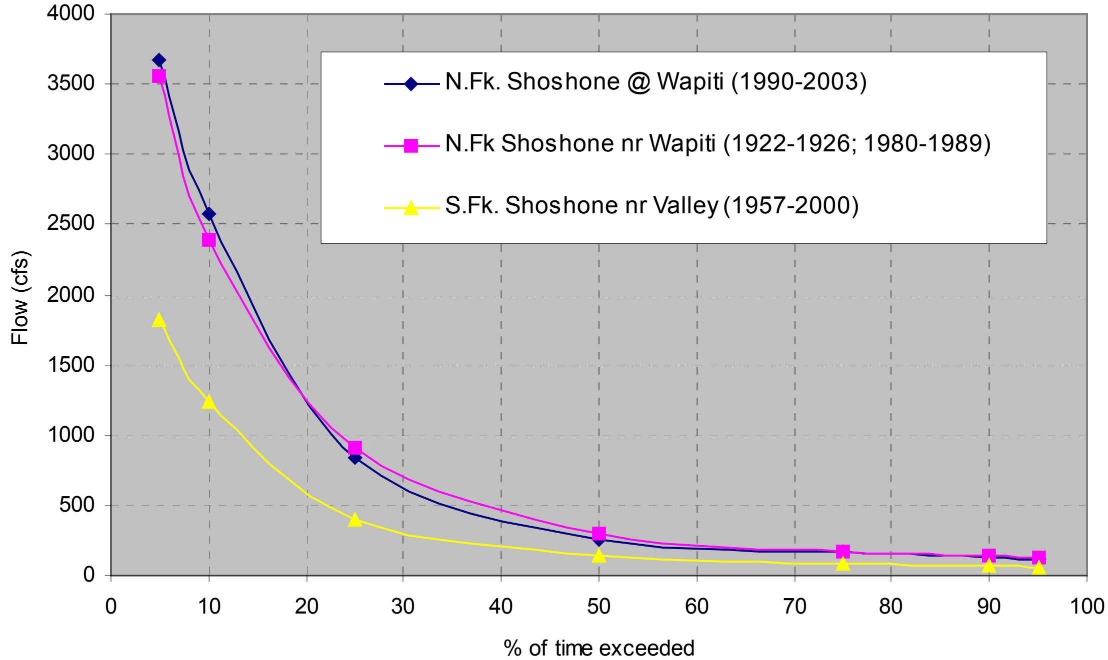

Figure 2. Flow exceedance curves for three USGS stream gage stations near Trout Creek (developed from Table 2 in HabiTech 2004).

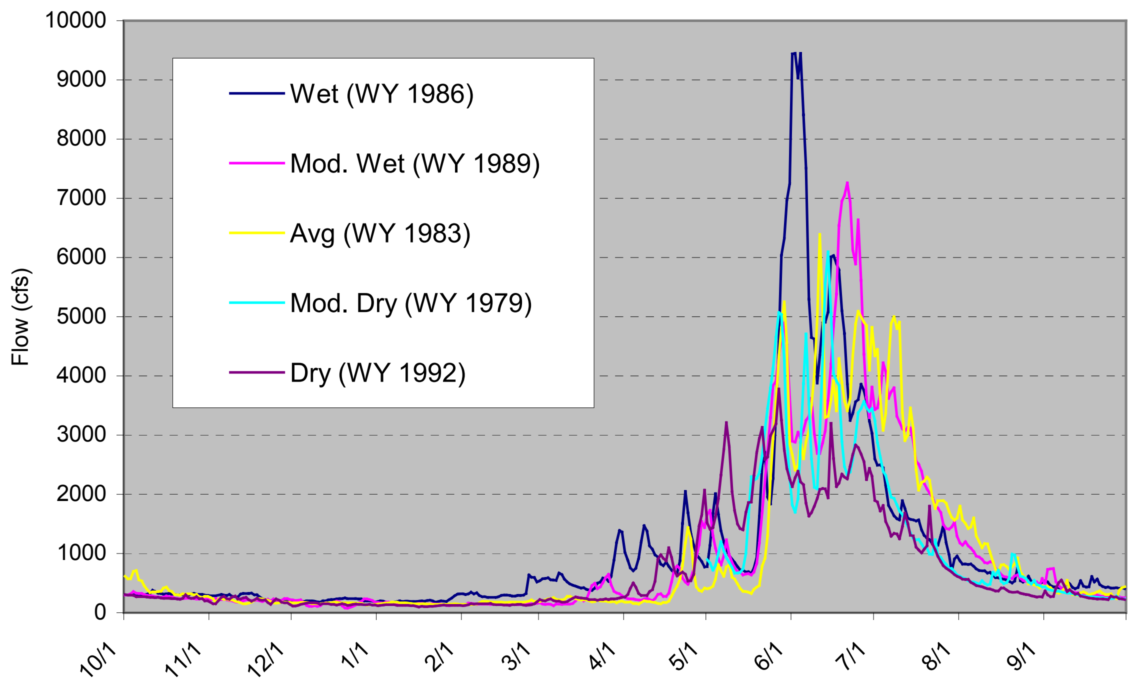

Figure 3. North Fork Shoshone River representative hydrographs from water years falling into five exceedance classes (wet 0-10%; moderately wet 10-30%; average 30-70%; moderately dry 70-90%; dry 90-100%).

Flow magnitudes and timing in tributaries like Trout Creek are likely to differ slightly on a local level from the North Fork Shoshone River gage data due to local precipitation patterns and other factors. But the long-term shape of the hydrograph should be similar to those illustrated above since the entire North Fork Shoshone basin upstream from Buffalo Bill Reservoir is relatively uniform in geology, land cover and management.

Upland and Riparian Resources

Upland vegetation in the Trout Creek basin ranges from shrub-grassland steppe at lower elevations through montane coniferous forests to high elevation alpine moss-lichen-forb communities. Intermixed barren rock outcrops, cliffs and talus slopes provide contrast in an otherwise unbroken conifer sea. Spruce-fir forests blanket mid-elevation regions of the Trout Creek basin, especially on north facing slopes. South slopes and ridge tops often contain open grass or shrub communities and whitebark pine (at elevations generally above 8500 feet) while limber pine and junipers occur occasionally. A severe outbreak of fir beetles during drought in the late 1990s and early 2000s has resulted in high Douglas fir mortality throughout the North Fork Shoshone basin, including the Trout Creek basin.

Riparian irrigated meadows and cottonwood stands occur on private land for the 3.8 miles between the mouth and the Forest Service boundary. Beaver are active in this reach. From the Forest Service boundary upstream to the confluence with Robbers Roost Creek, the riparian zone contains a mix of shrubs (mostly willow and water birch), multiple-age cottonwood stands, occasional conifers, and moderate herbaceous growth. The riparian zone extends from about 10 to 100 feet on each side of the stream through this segment, growing narrower in an upstream direction. Upstream of Robbers Roost Creek, shrubs are still common in the riparian zone but conifers are increasingly present.

Moon Crest Ranch leases the Shoshone National Forest portion of the Trout Creek basin for cattle grazing. The lease allows up to 650 cow-calf pairs from mid-June through October. The bulk of the grazing occurs in the Robbers Roost drainage under a deferred rest rotation. In recent drought years, the actual grazing use has been less than the permitted numbers, season and area (Mary Ritz, Shoshone National Forest, personal communication). There has been no timber management activity in the basin. Prescribed burns have been conducted in recent years to reduce fuels, improve wildlife habitat and increase livestock forage. Trout Creek Ranch raises horses and a few cattle. In addition, Trout Creek Ranch has irrigated alfalfa meadows along Trout Creek.

Fishery Resources

The fish community in the North Fork Shoshone River basin upstream of Buffalo Bill Reservoir includes native YSC (Figure 4), mountain whitefish *Prosopium williamsoni*, mountain sucker *Catostomus platyrhynchus*, longnose sucker *Catostomus catostomus* and longnose dace *Rhinichthys cataractae*. Introduced species include RBT, brook trout *Salvelinus fontinalis* and brown trout *Salmo trutta*. Amphibians include leopard frog *Rana pipiens*, boreal chorus frog *Pseudocris triseriata maculata*, Columbia spotted frog *Rana luteiventris* and boreal toad *Bufo boreas*.


Figure 4. Yellowstone cutthroat trout (photo by Wyoming Game & Fish Department).

In the past, the fishery management focus in the North Fork basin was on providing diverse angling opportunities by supplementing natural populations with stocked fish. Cutthroat trout, brook trout and RBT were stocked throughout the North Fork Shoshone drainage from the early 1900s until the late 1980s. The lower reaches of Trout Creek received planted trout into the late 1950s. The North Fork drainage is currently managed as a wild trout fishery with native YSC a vital component of that fishery. Trout Creek headwaters were stocked in 1993, 1999, 2001, 2003, and 2005 to restore genetically pure YSC to the drainage above impassable waterfalls upstream from the confluence of Singing Brook Creek. These fish movement barriers isolate the headwaters from downstream RBT and rainbow X cutthroat trout hybrids (RXC) and provide a refuge for pure YSC. Establishing and maintaining Trout Creek headwater populations enhances the status of Yellowstone cutthroat trout range wide. Secondarily, this restoration stocking may positively influence the downstream YSC population as pure juvenile and adult fish from upstream areas drift downstream and contribute their genes.

The primary fish species in Trout Creek are YSC, RBT and RXC. Mountain sucker, longnose dace and mountain whitefish in Trout Creek are reported rare in WGFD records. Brown trout have also been sampled rarely near the confluence with the North Fork Shoshone. The WGFD considers Trout Creek an important spawning tributary for large YSC that ascend the river each spring from Buffalo Bill Reservoir. Because it is the first major tributary above Buffalo Bill Reservoir where trout over-winter, Trout Creek annually receives a large spawning run. Trout Creek is believed to function as a nursery in which fry and juvenile trout grow and eventually migrate downstream to Buffalo Bill Reservoir. Nursery stream function is strongly suggested by sampling conducted in 1988-89 near the Trout Creek mouth and in 1990, 1999, 2000 and 2001 on the National Forest which yielded relatively large numbers of juvenile (less than 6 inches total length) and young-of year (less than 3 inches total length) trout (for additional details, see WGFD Fish Division Progress Reports for 1999-2003). Finally, a large number of juvenile trout were observed during snorkel observations in 2004 (see Habitat Suitability Criteria section later in this report), further suggesting a strong nursery role for Trout Creek.

Kruse et al. (2000) surveyed YSC status in the Greybull River, South Fork Shoshone and North Fork Shoshone River basins. In the North Fork Shoshone, they did not recognize any pure populations but rather characterized a hybrid swarm in which some apparently pure YSC coexisted with hybridized and pure RBT. Kruse et al. (2000) suggest individual Yellowstone cutthroat that appear pure may in fact be hybrids. An alternative explanation is that pure populations remain in the basin even though reproductive isolating mechanisms have not been identified. During snorkel observations in 2004, we observed apparently pure YSC, RBT, and RXC in Trout Creek.

One of the foremost challenges for the fishery in Trout Creek and associated North Fork Shoshone River and Buffalo Bill Reservoir, is fish loss to irrigation ditches. The four diversions on Trout Creek Ranch provide ample potential for loss of out-migrating adults, juveniles, and young-of-year trout. In September 2003, Cody Region fish managers sampled the ditches using backpack electrofishing gear and found high numbers of young-of-year trout (WGFD 2003). In recognition of this issue, Trout Creek Ranch and other landowners have been working proactively with the East Yellowstone Chapter of Trout Unlimited, the WGFD and the U.S. Fish and Wildlife Service to design and install structures to alleviate fish loss. In 2004 – 2005, a roller screen and fish bypass was constructed in the most-downstream ditch and this was operated throughout the 2005 irrigation season. Plans are being developed and implemented to install additional devices to exclude fish from the remaining three ditches.

Another significant fishery issue is the potential for de-watering of the stream channel during the irrigation season and the effect of that de-watering on fish movement and survival. While the study and instream flow segment described in this report will provide fishery protection to upstream waters, it will not alleviate or impact water issues on the short but critical lower stream reach between the Forest Service boundary and the confluence with the North Fork Shoshone River (because the instream flow water right will be junior to all other existing water rights on the stream). Opportunities should be pursued to work with landowners to find solutions that meet the needs of both water users and the stream environment.

Instream Flow Segment

The lower 3.5 miles of Trout Creek abut privately owned land (Figure 5). Next upstream, the stream crosses a small BLM parcel for 0.3 miles. The remaining headwaters occur on the Shoshone National Forest. From measurements on 1:24,000 scale maps in AllTopo V7 (iGage 2003), Trout Creek extends nearly 12 miles on National Forest. Including all the perennial tributaries on a 1:24,000 scale map, there are approximately 118 stream miles in the drainage network above the Forest Service boundary.

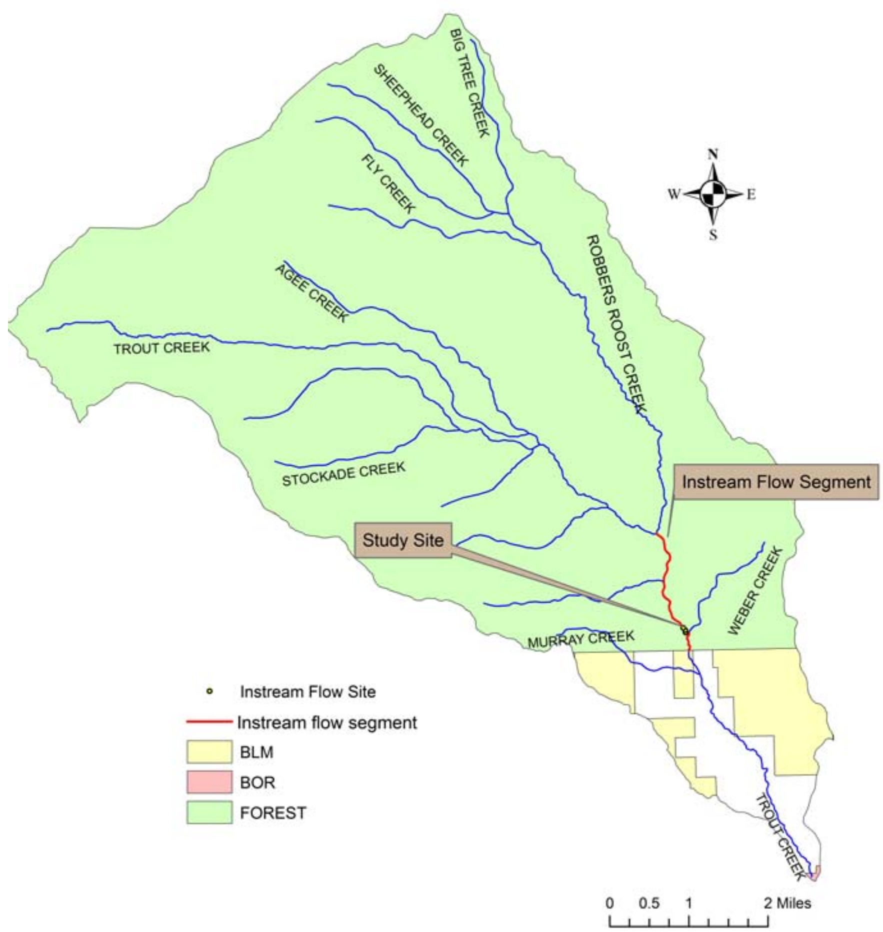

Figure 5. Trout Creek instream flow segment.

A two-mile long instream flow segment was identified from Robbers Roost Creek downstream to the Forest Service Boundary (Figure 5, Table 4). The lower boundary was identified because it marks the beginning of public land. The upper boundary marks a significant hydrologic break where Trout Creek upstream of Robbers Roost Creek is likely to have markedly less water and a different relationship between habitat and water quantity.

Table 4. Trout Creek instream flow segment. Coordinates and lengths from AllTopo® software.

Length (mi)	Approximate UTM (Z12, NAD27)		Segment Description
	Upper	Lower	
2.0	628500E, 4933242N	628184E, 4930856N	Robbers Roost Creek downstream to Forest Service boundary

This instream flow segment will indirectly protect over 100 stream miles in the upper Trout Creek basin. Indirect protection comes by virtue of the fact that any new water users in the headwaters must pass enough water to fulfill the downstream senior instream flow appropriation. The indirectly protected headwaters are home to restored populations of genetically pure Yellowstone cutthroat trout. The instream flow segment will directly protect two miles of Trout Creek that provides important spawning and rearing habitat for a population of YSC and RBT associated with the North fork Shoshone River and Buffalo Bill Reservoir.

METHODS FOR DEVELOPING FISH FLOW RECOMMENDATIONS

This section presents methods used in developing fish flow recommendations for a Trout Creek instream flow water right application. However, if flows are limited to only the instream flow water right recommendations developed from these methods, the fishery will suffer over the long-term because annual patterns of floodplain inundation and sediment flux would not be functioning to maintain the stream channel and associated habitat. Channel maintenance flow recommendations are developed in Appendix 1 to address a broader interpretation of fishery maintenance. Should opportunities arise in the future to secure instream flow water rights for long-term maintenance of Trout Creek aquatic environments, Appendix 1 will provide a valuable reference.

Yellowstone cutthroat trout are a high priority and the primary reason Trout Creek was selected for an instream flow water right. Trout Creek provides habitat for adult (≥6 inches), spawning, juvenile (3-6 inches) and fry (<3 inches) YSC. Flow recommendations will consider all these life stages. While lower Trout Creek also has other introduced salmonids, most notably rainbow trout, the management focus is on improving YSC habitat. Flow recommendations for rainbow trout are not considered.

Four additional fish species are native to the North Fork Shoshone basin but little information exists about their historic occupation of Trout Creek. Mountain whitefish prefer deep, fast conditions generally found in larger rivers (Baxter and Stone 1995) and it is unlikely Trout Creek on the Shoshone National Forest historically provided habitat to sustain populations. Mountain sucker are believed to be widespread and stable in Wyoming though their habitat is believed declining or vulnerable (Weitzel 2002a). Ideally, physical habitat estimates for mountain sucker as a function of Trout Creek flow would be developed in this study. However, there are no historical records of mountain sucker in Trout Creek and even if there were, the depth, substrate and velocity requirements of this species are largely unknown. Longnose dace and longnose sucker are considered widespread, abundant and secure in Wyoming (Weitzel 2002a and 2002b). Little is known about specific depth and velocity requirements of these fish species (Edwards 1983). Since their habitat requirements are uncertain and their status at this time appears secure, instream flow recommendations did not target these species.

Estimating Trout Creek Hydrology

HabiTech, Inc. (Laramie, WY) estimated mean annual flow (also called "average daily flow" or ADF), annual flow duration, monthly flow duration, and flood frequency for the Trout Creek instream flow segment (HabiTech 2004). HabiTech calculated average daily flows from the contributing basin area model of Miselis et al. (1999). This model was developed from gages in Absaroka Mountain streams and is similar to the approach of Lowham (1988). The basin area at the downstream end of the instream flow reach was used. A dimensional analysis approach was used to develop both annual and monthly flow duration information. Dimensionless duration tables were created for the South Fork Shoshone near Valley gage by dividing each duration class by the mean annual flow (i.e., Q_W / Q_{AA}). The dimensionless flow value for each annual and monthly percentile was then multiplied by the estimated average annual flow to develop flow duration values. A similar approach was used to develop the flood frequency series. For further details, see HabiTech (2004).

The basin area approach used by HabiTech (2004) is based on Absaroka Mountain gage data to more accurately reflect local conditions. Alternative approaches for estimating Trout Creek hydrology include applying the Lowham (1988) basin characteristic approach or the recently refined basin characteristic approach described in Lowham et al. (2003). These methods result in similar or higher flow estimates. For example, HabiTech (2004) calculated 32 cfs average daily flow compared to 31 cfs using Lowham (1988). In another example, applying Lowham (2003) yields an October average flow of 28 cfs compared to 17 cfs from the Miselis et al. equation. HabiTech (2004) estimates an October 50% duration flow of 12 cfs. Differences on this order are consistent for all months and tributaries. Therefore hydrology estimates used in this report are likely conservative and, if in error, are most likely lower than actually occur in the streams.

Average daily flow estimates from the HabiTech report were used in applying the Habitat Quality Index and Habitat Retention models (described below). The 1.5-year return interval on the flood frequency series was used to estimate bankfull flow (Rosgen 1996) for use in the Habitat Retention model and for developing channel maintenance flow recommendations (Appendix 1). Channel maintenance calculations also used the 25-year peak flow estimate from HabiTech (2004). The monthly flow duration series was used in developing winter flow recommendations. Throughout this report, the term "exceedance" is used, as in "20% exceedance flow". The 20% exceedance flow refers to the flow level that would be exceeded 20% of the time. As such, it is a higher flow level than the 50% or 80% exceedance flow.

Flow measurements collected during instream flow habitat studies are included in this report (Table 7). HabiTech (2004) compared their hydrological estimates to these flow measurements and concluded that their predictions were reliable.

Predicting Fish Habitat Using Instream Flow Models

The term "habitat" is used frequently in this report. In most applications, "habitat" refers to the physical conditions of depth, velocity, substrate and cover – variables that change when discharge changes. A full trout habitat description also includes temperature, dissolved oxygen, distribution and abundance of prey and competitor species, movement timing and extent, and other variables. The "physical" habitat modeled and discussed in this report covers the important dimensions of trout habitat that vary predictably as a function of flow. It is assumed that these aspects of trout habitat are important to the health and short-term persistence of trout populations.

Three modeling approaches described below were used to generate monthly fish-based instream flow water right recommendations for April through September. Development of fish flow recommendations for the winter (October through March) is described in a separate section. Channel maintenance flow requirements are described in Appendix 1.

Physical Habitat Simulation

The Physical Habitat Simulation (PHABSIM) system of computer models calculates a relative suitability index for target species like YSC as a function of flow based on depth, velocity, and substrate or cover (Bovee et al. 1998). Calculations are repeated at user-specified discharges to develop a relationship between suitable area (termed "weighted useable area" or WUA) and discharge. Model calibration data are collected across the stream at each of several locations (transects) and involve measuring depth and velocity at multiple locations (cells) along each transect. Measurements are repeated at three or more different discharge levels. By using depths and velocities measured at one flow level, the user calibrates a PHABSIM model to accurately predict the depths and velocities measured at the other discharge levels (Bovee and Milhous 1978, Milhous et al. 1984, Milhous et al. 1989). Following calibration, the user simulates depths and velocities over a range of user-specified discharges.

Next, the predicted depths and velocities, along with substrate or cover information, are compared to habitat suitability criteria (HSC). The relative value of predicted depths, velocities, substrates, and cover elements to fish are defined by HSC which range between "0" (no suitability) and "1" (maximum suitability). At any particular discharge, a combined suitability for every cell is generated. That suitability is multiplied by the surface area of the cell and summed across all cells to yield weighted useable area for the discharge level. Results are often depicted using graphs of WUA for a particular fish life stage versus a range of simulated discharges (Bovee et al. 1998). Developed relationships are best interpreted as a relative suitability index rather than a definitive prediction of physical area (Payne 2003).

<u>Developing Habitat Suitability Criteria for Physical Habitat Simulation</u>

Habitat suitability criteria were developed for adult (6 inches or greater total length) and juvenile (3 to 6 inches) YSC by measuring depth, velocity, substrate, and cover at trout locations in Trout Creek. Fish were located from the bank (May 26 and June 9, 2004) and from snorkeling (June 9 and July 14). Snorkel observations involved crawling or swimming slowly upstream through all habitats (Figure 6). When an undisturbed trout was observed, it was monitored for 3-8 minutes before recording average column velocity, focal velocity, total depth, and cover association. We collected bank observations by moving slowly upstream along the bank until an undisturbed trout was sighted, observing the trout for 3-8 minutes, and then recording habitat use information. Each fish was classified as one of the following: YSC, RBT, RXC (based on cutthroat markings and white fin margins) or unknown.

Figure 6. Snorkeling in Trout Creek to locate Yellowstone cutthroat trout for habitat suitability criteria.

Frequency-of-habitat-use distributions were developed for depth and average column velocity. The non-parametric tolerance interval method was used to develop habitat suitability criteria (HSC) for depth and velocity at a confidence limit of 90% (Slauson 1988). Suitability was defined on a scale of 0.0 to 1.0 where 1.0 indicates optimal suitability. Suitability scores of 1.0, 0.5, 0.2, and 0.1 were assigned to the central 50%, 75%, 90%, and 95%, respectively, of parameter range. Non-parametric tolerance limits were determined from Table 1 in Slauson (1988) at the 90% confidence level.

Spawning Yellowstone cutthroat trout were observed on May 26 and June 9, 2004 however too few (n=4) were located for HSC development. Thurow and King (1994) collected measurements at 66 spawning YSC locations in Idaho on a Snake River tributary similar in size to Trout Creek. These data were used to construct spawning HSC. No searches were conducted for fry. Rather, fry HSC were developed from measurements reported in Bozek and Rahel (1992).

Habitat Retention

The Habitat Retention Method (Nehring 1979; Annear and Conder 1984) was used to identify the flow that maintains selected values of depth, velocity and wetted perimeter in riffles (Table 5). Maintaining depth, velocity and wetted perimeter criteria in riffles ensures that other habitat types like runs or pools remain viable (Nehring 1979). Fish passage between habitat types and benthic invertebrate survival are considered adequate at the flow level identified by the Habitat Retention Method. The flow identified by the Habitat Retention Method is important year-round except when higher instream flows are required to meet other fishery management purposes.

Table 5. Hydraulic criteria for determining maintenance flow with the Habitat Retention Method (Annear and Conder 1984).

Category	Criteria
Mean Depth (ft)	0.20
Mean Velocity (ft/s)	1.00
Wetted Perimeter[a] (%)	50

[a] - Percent of bankfull wetted perimeter

Simulation tools and calibration techniques used for hydraulic simulation in PHABSIM are also used with the Habitat Retention approach. The difference is that Habitat Retention does not attempt to translate depth and velocity information into conclusions about the amount of physical space suitable for trout life stages. The Habitat Retention Method focuses on riffle hydraulic characteristics so that fish passage and invertebrate production is maintained. The AVPERM model within the PHABSIM methodology is used to simulate cross section depth, wetted perimeter and velocity for a range of flows. The flow that maintains 2 out of 3 criteria in Table 5 for all riffle transects is then identified.

Habitat Quality Index

The Habitat Quality Index (HQI; Binns and Eiserman 1979; Binns 1982) was used to determine trout habitat levels over a range of late summer (July through September) flow conditions. Most of the annual trout production in Wyoming streams occurs during the late summer, following peak runoff, when longer days and warmer water temperatures stimulate growth. The HQI was developed by the WGFD to measure trout production in terms of nine biological, chemical, and physical trout habitat attributes. Each attribute is assigned a rating from 0 to 4 with higher ratings representing better trout habitat. Attribute ratings are combined in the model with results expressed in trout Habitat Units (HU's), where one HU is defined as the amount of habitat quality that will support about 1 pound of trout.

In the HQI analysis, habitat attributes measured at various flow events are assumed to be typical of late summer flow conditions. For example, stream widths measured in June under high flow conditions are considered an estimate of stream width that would occur if that flow level were a base flow occurring in September. Under this assumption, HU estimates are extrapolated through a range of potential late summer flows (Conder and Annear 1987). Linear equations of velocity and cover at different flow levels were used to calculate ratings. In calculating Habitat Units over a range of discharges, temperature, nitrate concentration, invertebrate numbers, and eroding banks were held constant. HQI results were used to identify the flow between July 1 and September 30 needed to maintain existing YSC production (Table 6).

Article 10, Section d of the Instream Flow statute states that waters used for providing instream flows "shall be the minimum flow necessary to maintain or improve existing fisheries". The HQI is used to identify a flow to maintain the existing fishery in the following manner: the number of Habitat Units that occur under normal July through September flow conditions is quantified and then the flow that maintains that level of habitat is identified. To define July through September flow conditions, we review both measured flows and estimated 50% monthly exceedance flows for the July through September period. The August 50% monthly exceedance flow was used as a reasonable estimate of normal late summer flow levels and is consistent with how the HQI was developed (Binns and Eiserman 1979).

Maintaining Fish Habitat In Winter

Natural winter (October through March) flow levels are recommended to maintain the YSC populations in Trout Creek. The following discussion provides the basis for this recommendation.

Scientific understanding of winter trout habitat and the interaction between trout behavior, their habitat and ice and snow has increased considerably over the last 60 years (Needham et al. 1945, Reimers 1957, Butler 1979, Cunjak 1988, Cunjak 1996, Prowse 2001a and 2001b, Greenberg et al. 2005). Prowse (2001a and 2001b) provides an extensive review of the wide range of effects ice processes have on the hydrologic, biologic, geomorphic, water quality and connectivity characteristics of riverine resources and fisheries. Ice processes in particular may limit habitat. For example, suspended ice crystals (frazil ice) can cause direct trout mortality through gill abrasion and subsequent suffocation. Frazil ice may also indirectly increase mortality by limiting available habitat, causing localized de-watering, and causing excessive metabolic demands on fish forced to seek ice-free habitats (Brown et. al 1994, Simpkins et al. 2000, Annear et al. 2002, Barrineau et al. 2005, Lindstrom et al. 2004). Pools downstream from high gradient frazil ice-forming areas can accumulate anchor ice when woody debris or surface ice provides anchor points for frazil crystals (Brown et. al 1994, Cunjak and Caissie 1994). Such accumulations may result in mortalities if low winter flows or ice dams block emigration.

Mortalities can occur if fish are forced to move when water temperatures are near freezing, such as to avoid the physical effects of frazil ice or if changing hydraulic conditions force them to find areas of more suitable depth or velocity. The extent of impacts is dependent on the magnitude, frequency and duration of frazil events and the availability of alternate escape habitats (Jakober et al. 1998). Juvenile and fry life stages are typically impacted more than larger fish because younger fish inhabit shallower habitats and stream margins where frazil ice tends to concentrate. Larger fish that inhabit deeper pools may endure frazil events with little effect if they are not displaced. In contrast, refuge from frazil ice may occur in streams with groundwater influx, pools that develop cap ice or segments where heavy snow cover causes stream bridging (Brown et al. 1994). Recent studies in Wyoming document complex interactions between localized ice conditions and trout habitat suitability (Barrineau et al. 2005).

The complexities of variable icing patterns (for example, frazil and surface ice often appear and disappear over widely ranging spatial and temporal scales) make direct modeling of winter trout habitat highly difficult, if not impossible. Even cases that can be modeled, for example a stable ice cap over a simple pool, may not yield a result worthy of the considerable time and expense necessary to calibrate an ice model. The IFC (Annear et al. 2004, Pp. 106) recognizes the challenges of developing winter flow prescriptions with the following statement:

Unfortunately, the tools to quantify the relation between flow and favorable ice conditions, and habitat, are limited at this time. In the face of this uncertainty, managers should take a conservative approach when their actions or those of others will result in modification of winter flow regimes, either by additions or depletions.

For Wyoming Rocky Mountain headwater streams, a conservative approach to meeting the instream flow law's requirement of developing flow recommendations to maintain existing fisheries is to simply recommend the existing natural winter flow level. That approach was adopted for Trout Creek. The scientific literature indicates that already harsh winter habitat conditions would become more limiting if winter water depletions were to occur and force trout to move more frequently, change the frequency and severity of ice formation, distribution and retention, and reduce the trout holding capacity of the few large pools.

Indirect methods, such as the Habitat Retention Method employed by the WGFD, are an alternative way of indexing winter trout habitat changes to flow and this approach was used in the past to set winter flow recommendations for many instream flow segments. Habitat Retention analyses are still conducted to ensure that riffle hydraulics are maintained under ice-free conditions. When natural winter flows in mountain streams are greater than those from Habitat Retention, the natural winter flow will become the instream flow recommendation.

Another indirect method is developing hydrologic standards for universal application across Wyoming. Hubert et al. (1997) found this approach deficient due to the variable nature of winter trout habitat among streams and poor gage records often associated with the winter season. For this reason, we do not believe the 50% monthly exceedance provides an appropriate estimate of naturally occurring winter flow. It is more conservative from the standpoint of maintaining fisheries to recommend the higher flows of a 20% monthly exceedance. This assures that even in cases where flow is underestimated due to poor gage records or other estimation errors, flow levels approximating the natural winter condition will be recommended.

Combining Methods to Arrive at Instream Flow Recommendations

The fishery functions and associated time periods summarized in Table 6 show how each of the models and approaches described above were applied to Trout Creek on a seasonal basis. The instream flow recommendation for any month where two or more recommendations apply is based on the recommendation that yields the higher flow. Natural flows during the October through March winter months are recommended for high mountain streams like Trout Creek (Table 6). The Habitat Retention approach provides a base flow but is not used for instream flow recommendations when other aspects of fishery maintenance require higher flows.

Table 6. Yellowstone cutthroat trout life stages and months considered in developing instream flow recommendations. Numbers indicate the method used to determine flow requirements and green shaded cells indicate primary methods for flow recommendations.

Life Stage and Fishery Function	JAN	FEB	MAR	APR	MAY	JUN	JUL 1-15	JUL 16-31	AUG	SEP	OCT	NOV	DEC
Survival and movement of all life stages	1	1	1	2	2	2	2	2	2	2	1	1	1
Spawning habitat				3	3	3	3						
Fry habitat									3	3	3		
Juvenile habitat	3	3	3	3	3	3	3		3	3	3	3	3
Adult habitat	3	3	3	3	3	3	3		3	3	3	3	3
Adult growth							4	4	4	4			
All life stages habitat*				5	5	5	5						

1=Natural winter flow or Habitat Retention, whichever is greater, 2=Habitat Retention, 3=Physical Habitat Simulation, 4=Habitat Quality Index, 5=Channel Maintenance.

* Channel maintenance flow recommendations are developed in Appendix 1.

Spawning results from PHABSIM provide flow recommendations during April though June and July 1 – July 15th, when the majority of spawning activity occurs in Trout Creek and the North Fork Shoshone River (Kent 1984). Spawning recommendations are applied up through mid-July in Trout Creek to maintain habitat for late-spawning fish. The North Fork Shoshone River has high, post-peak flows in early July (Figure 3) and YSC are known to spawn on the descending limb of the hydrograph (Thurow and King 1994).

PHABSIM results for adults, juveniles, and fry were examined to ensure adequacy of flow recommendations from other methods throughout the year. The HQI applies to adult trout growth during the months of July, August and September and is the default method for those months. Channel maintenance flows perform their function during runoff in April, May, June and July but will not be used in the instream flow water right application as described in the Introduction.

Collecting Data at a Study Site

A 761-foot study site was selected after walking the length of the identified instream flow segment on May 3, 2004. During this reconnaissance inspection, the distribution of trout habitat, location and relative magnitude of tributary water sources, and other features were noted. A single study site was established at a location (UTM 629040E, 4931283N, Z12, NAD27) offering the range of features judged to be representative of the entire reach. Riffles, runs, pools, spawning gravel, and stream-margin fry habitat were present (Figure 7). The study site was near the downstream end of the instream flow segment.

The study site was visited on multiple dates to measure habitat features under a range of flow conditions (Table 7). In addition to collecting measurements for the HQI, PHABSIM and Habitat Retention models, a Rosgen Level 2 channel survey was conducted (Rosgen 1996). This involves measuring channel pattern, profile, dimension, and sediment size (Appendix 3). This geomorphic information serves to classify the stream type and provides a basis for addressing questions of sediment supply, stream sensitivity to disturbance, channel response to flow regime changes and fish habitat potential. The data are also important for developing channel maintenance flow requirements. Channel measurements collected include measurements of at least 100 substrate particles, cross sectional area, longitudinal profile, and multiple bankfull width measurements. Channel pattern measurements of sinuosity, belt width, and meander length were obtained from digital ortho quarter quadrangles (DOQQ's) using ArcGIS software.

Relative percentages of "macrohabitat" (e.g., pools, riffles, runs) were determined using the classification scheme of Hawkins et al. (1993). Under this approach, channel units such as pools, riffles, and runs are identified by relative channel gradient, water velocity, surface turbulence, and depth. Channel unit lengths were determined by recording the paced length (about 3 feet per pace) of each channel unit encountered over a stream distance of at least 20X the bankfull width. Percentages of each macrohabitat were used to weight transects in PHABSIM modeling.

Table 7. Dates and discharges when measurements were collected in 2004 at the Trout Creek study site.

Date	Discharge (cfs)	Data Collected
May 3	8.5	Site reconnaissance
May 25	11	HQI, PHABSIM
May 26	11	HQI, PHABSIM, trout observations
June 8	30 – 31	HQI, PHABSIM
June 9	~25 - 30	Trout observations
July 13	21	HQI, PHABSIM, cross section & profile survey
July 14	~21	Trout observations
August 19	8.7	WHAM*, pebble count

* Wyoming Habitat Assessment Methodology (Quist and Hubert 2004). The WHAM provides a general description of watershed features.

Figure 7. Trout Creek at 11 cfs (top), 30 cfs (middle), and 21 cfs (bottom). Tape in bottom photo is across riffle transect nine.

Transects for collecting PHABSIM data were distributed with four transects in each of three separate pool-run-riffle sequences and an additional 3 transects in a rapid for a total for 15 transects. The 761–foot HQI reach extended between the upper (transect #15) and lower transect (transect #1).

PHABSIM for Windows Version 1.2 was used and six PHABSIM "projects" were created. Each of the three separate pool-riffle habitat sequences was modeled in a separate project and each of the three rapid habitat transects was modeled individually. Water surface elevations for all transects were simulated using stage-discharge relationships. We assessed water surface predictions by looking for linearity of the log flow-log water surface elevation plot, low mean square error of regression, and parallel water surface profiles (Waddel 2001). In some cases, water surface elevation predictions were compared to those from a stage-backwater approach (WSP) but in all cases the stage – discharge approach performed adequately. For transects 1-9, the velocity set collected at 30-31 cfs served as the calibration source for distributing roughness among cells. Velocities measured at 11 cfs served this purpose for transects 10 – 15. Velocity calibration included comparison of predicted and measured velocities and examination of VAF plots (Waddel 2001). The HABTAE subprogram was used to generate weighted usable area for each transect, assuming a 1-foot long cell. For adult, juvenile and fry physical habitat, transects were combined by weighting each transect relative to the habitat type it represents and the proportion of that habitat in the stream. For spawning, simulation results from riffle transects were averaged. Physical habitat was simulated from 4 cfs to 100 cfs for all transects and from 4 cfs to 200 cfs for the riffle transects. Simulation increments of 1.0 cfs were used up to 30 cfs, 5 cfs increments were used from 30 cfs to 100 cfs, and 10 cfs increments were used above 100 cfs. Weighted useable area versus flow curves were generated for spawning, fry, juvenile and adult YSC.

Three riffle transects modeled with PHABSIM were used in the Habitat Retention analysis (numbered transects 1, 5 and 9). In calculating the wetted perimeter criterion (Table 5), bankfull discharge was estimated as the 1.5-year return interval flow of 250 cfs from HabiTech (2004). For applying the Habitat Retention depth criteria, an average daily flow of 32 cfs was used (HabiTech 2004). Average wetted stream width on the 15 transects at 32 cfs was less than 20 feet (from PHABSIM simulations) so 0.20 was used as the default depth criterion.

For HQI analysis, the critical period stream flow and annual stream flow variation attributes were calculated using average daily flow (32 cfs) and peak flow (250 cfs) estimates from HabiTech (2004). Maximum water temperature was determined with an Optic StowAway® temperature recorder set to monitor water temperature at 1-hour intervals between May 25 and August 19, 2004. The HQI "substrate" attribute, a measure of invertebrates per square foot of streambed, was rated visually.

Flows For Other Important Ecosystem Components

The foregoing sections focus primarily on narrowly defined methods for maintaining short-term fish habitat. Additional biological issues include maintaining diverse riparian and floodplain vegetation and the community of animals that use these habitats. Channel maintenance flow recommendations as described in Appendix 1 would promote a healthy riparian assemblage of plants and animals resembling that of today (Stromberg and Patten 1990; Rood et al. 1995; Mahoney and Rood 1998). Such flows would serve to maintain the existing B channel as described in the Geology section.

Existing Trout Creek water quality is excellent in and upstream of the instream flow segment. That is, water temperature, turbidity, and various organic and inorganic constituents are believed to be at normal levels for a fairly pristine Absaroka Mountain stream and no pollution is apparent (Kent 1984). Flow recommendations in this report are expected to maintain water quality within natural bounds. If new water development were to occur in the Trout Creek basin, water quality issues might bear re-examination.

RESULTS AND DISCUSSION

Hydrology

The hydrologic conditions were relatively dry during 2004 when the instream flow study was conducted. Mean annual daily flow at the North Fork Shoshone River at Wapiti gage for water year 2004 was 590 cfs compared to an 814 cfs average (15 years of record). Average May, June and July flows were at the 94%, 81%, and 75% exceedance levels for those months based on the 15 years of record. Precipitation in the Bighorn basin was less than long-term averages for most months from 2001 through 2003 but above average in 2004 (from the Western Regional Climate Center, www.wrcc.dri.edu). The relatively low flows in 2004 did not limit our ability to study fish habitat versus flow relationships for flows less than 100 cfs. However, our ability was limited in extrapolating to flows greater than 100 cfs except on the three riffle cross sections. On these transects, stage-discharge relationships performed reliably in simulating spawning habitat and hydraulic characteristics up to 200 cfs (see results below).

Table 8 lists key flow estimates from HabiTech (2004). Without a gage record on Trout Creek, there is no basis for a direct measure of the reliability of estimated flows. As expected, the six flows measured by WGFD in 2004 (Table 7) were less than the estimated 50% monthly exceedance flows (Table 8) and close to the 95% exceedance level. HabiTech (2004) discussed the reliability of their estimates and noted the WGFD measurements were within expectations and their approach based on the Miselis model yielded reasonable results. No evidence of bankfull or higher flows was observed during the eight visits in 2004. For example, peak flow at the North Fork Shoshone River gage in 2004 occurred between June 6 and June 10. Trout Creek was visited June 8 and the measured 30-31 cfs was well below the bankfull level indicated by a break in the cross-section profile and a flat floodplain depositional area (Figure 7).

Table 8. Trout Creek instream flow segment estimated hydrologic characteristics (HabiTech 2004).

Flow parameter		Estimated Flow (cfs)
	Mean Annual	32
	1.5 year peak	250
	25 year peak	555
Spring Month	HabiTech 50% Exceedance (cfs)	HabiTech 95% Exceedance (cfs)
April	9.4	5.2
May	46	12
June	119	52
Summer Month	HabiTech 50% Exceedance (cfs)	HabiTech 95% Exceedance (cfs)
July	73	23
August	24	12
September	15	9.0
Winter Month	HabiTech 20% Exceedance (cfs)	HabiTech 95% Exceedance (cfs)
October	15	7.7
November	10	5.0
December	7.7	4.1
January	6.9	4.3
February	6.4	4.2
March	7.1	4.4

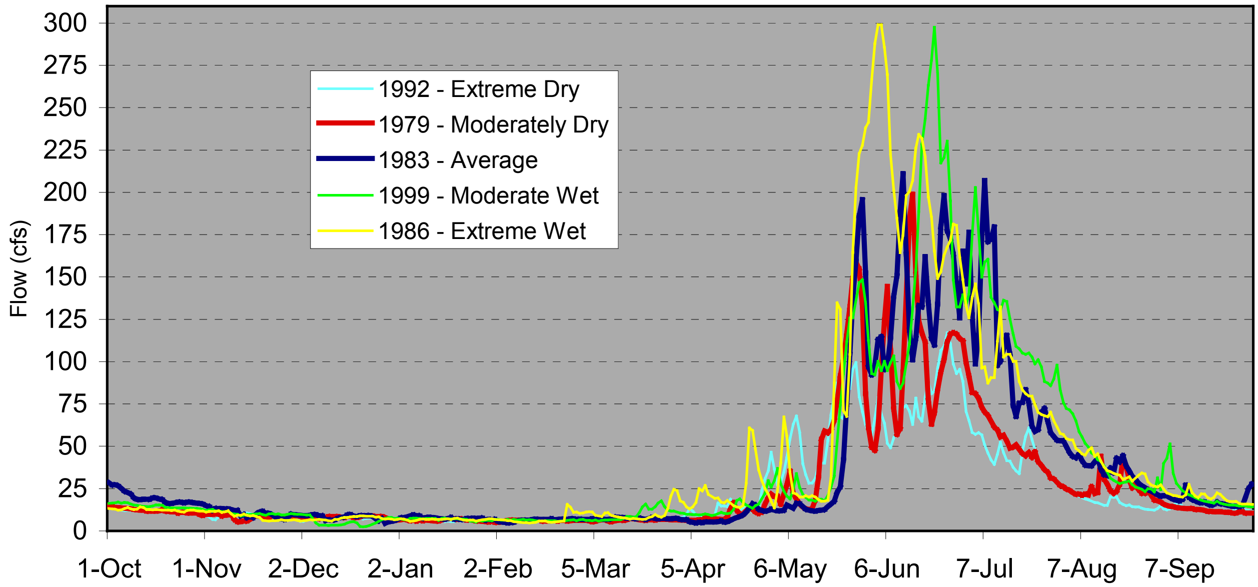

Figure 8. Trout Creek representative hydrographs from water years falling into five exceedance classes (wet 0-10%; moderately wet 10-30%; average 30-70%; moderately dry 70-90%; dry 90-100% (from HabiTech 2004).

Hydrographs for randomly selected water years falling into dry through wet exceedance classes display strong similarities among years (Figure 8). Winter flow levels are universally low and similar among years. Greatest differences among years occur in the ascending and descending limbs of the hydrographs during the months of May and July when weather patterns influence the timing of runoff and the occurrence of multiple melting cycles.

Development of Fish Flow Recommendations

Physical Habitat Simulation

The macrohabitat survey covered 1,012 paces (approximately 3036 feet) of stream channel including the study site and tallied 78% fast-water channel units and 22% slow-water units (pools). Rapids were the most frequent fast water category (50%), followed by riffles (20%) and runs (8%). Lateral scour pools were the most frequently identified pool types.

Depth and velocity were measured at the positions occupied by 56 adult trout (length ≥ 6 inches) located May 26, June 9, and July 14, 2004 in Trout Creek. Of these, 32 fish were judged to be pure Yellowstone cutthroat trout based on morphological characteristics and these trout were used to develop habitat suitability criteria (Figure 9). Most (27) trout were found in pools with the rest in rapids (3) or runs (2). Ten of these trout were within four feet of instream cover, usually woody debris or root wads. Highest suitability for adult trout was assigned to depths of 1.15-1.60 feet and average column velocities of 0.36-1.91 ft/s (Appendix 2). Substrate at trout locations was sand, gravel or cobble.

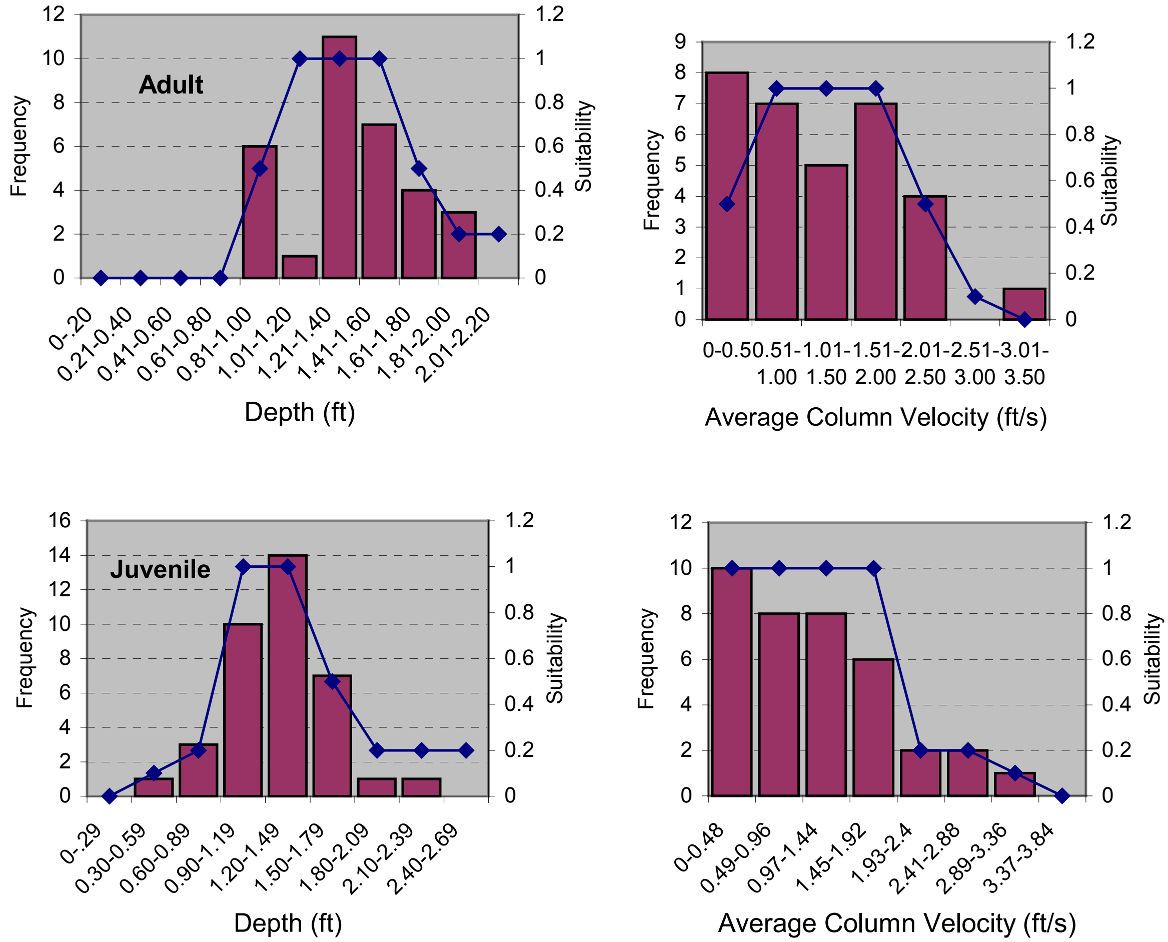

Figure 9. Trout Creek adult (n=32, upper graphs) and juvenile (n=37, lower graphs) Yellowstone cutthroat trout frequency-of-use observations and suitability criteria.

Juvenile trout (3-6 inch) used slightly shallower and slower water than adults (Figure 9). Juvenile trout were more likely to be found in rapids (n=12) than adults, though most were still located in pools (n=21). No pattern of juvenile location relative to the bank was observed: fish were located at distances of three to twelve feet from the nearest bank. Likewise, juveniles were near cover (usually woody debris or a boulder) in some cases but 22 fish were not near any cover. Highest suitability for juvenile trout was assigned to depths of 1.0-1.5 feet and average column velocities of 0.38-1.65 ft/s (Appendix 2). Like adults, juvenile fish did not seem to be associated with specific substrate types but appeared to use sand, gravel and cobble in proportion to its abundance in the stream.

The WUA index of spawning habitat on three riffles is displayed in Figure 10. Since these curves depict a relative index to trout habitat, the jagged nature should be ignored with the focus on the overall pattern, range and relative flow at which peaks occur. Riffle 1 offers the highest suitability for spawning with relatively high levels from 8 to 30 cfs. Riffle cross section 5 offers a narrower range of high suitability between about 25 and 40 cfs. The average curve has peaks at 18 and 26 cfs. The indices show rapid declines in spawning habitat at higher or lower flows. At higher flow levels velocity is the primary basis for reduced suitability while declining depths at low flows are the primary limiting factor.

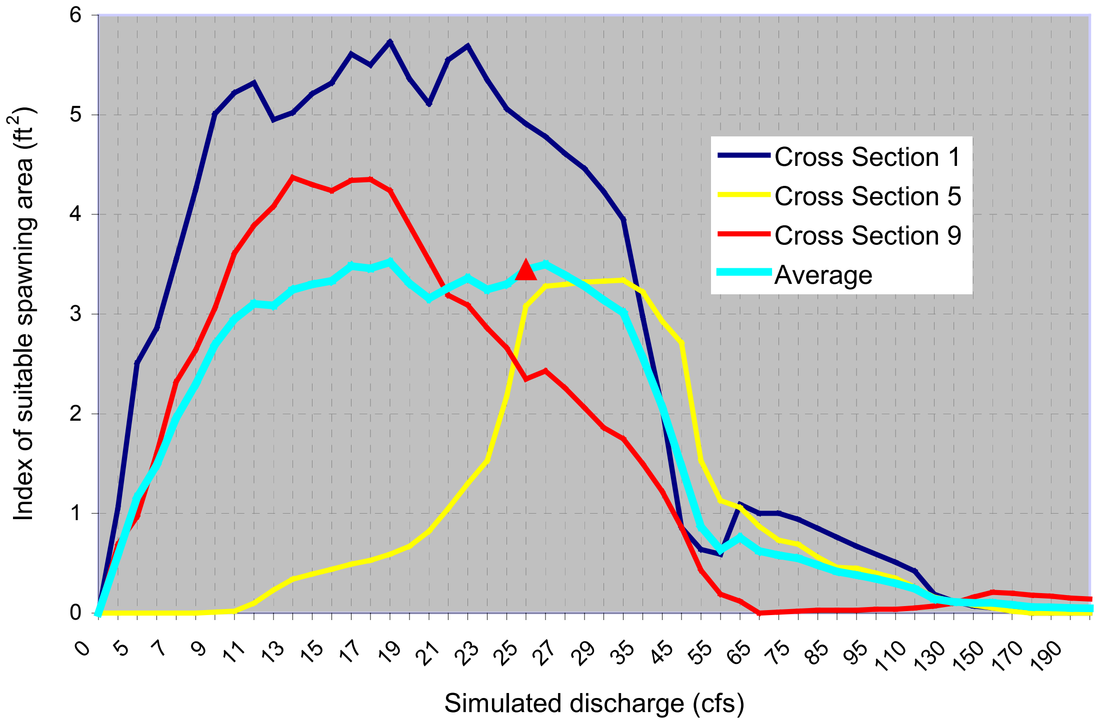

Figure 10. Yellowstone cutthroat trout spawning habitat (ft^2 per foot of stream length) on three riffle cross sections. X-axis values are scaled to show simulated flows and the triangle marker indicates a peak at 26 cfs on the average curve.

From the average spawning index curve, the flow peak at 26 cfs provides a strong basis for an instream flow recommendation (Figure 10). At 26 cfs, spawning suitability is relatively high on all three riffles in the study site compared to the peak at 18 cfs where only two of the riffles provide suitable spawning conditions. At flows less than 26 cfs, riffles with characteristics like those measured on riffle transect five will become less suitable for spawning. Providing highly suitable spawning habitat over a broad stream area (many riffles) in this case is preferred over the alternative strategy of maximizing spawning suitability on one or two riffles. Therefore, an instream flow of 26 cfs is recommended. This recommendation applies to April, May, June and July. Although the full 26 cfs may not always be present during this entire period, protection of flows up to 26 cfs will maintain adequate spawning habitat and therefore maintain the existing fishery.

The physical habitat indices for juvenile and adult YSC generally show increases with flow (Figure 11). A rapid decline in the juvenile index occurs at flows less than about 15 cfs and a relatively rapid decline in the adult index occurs below about 13 cfs (Figure 11). Since fry prefer shallow, slow water, the suitability of the stream channel for fry generally declines as flow increases over the modeled range. Higher modeled flows (>100 cfs) may reveal increases in fry suitability as backwaters and channel margins flood.

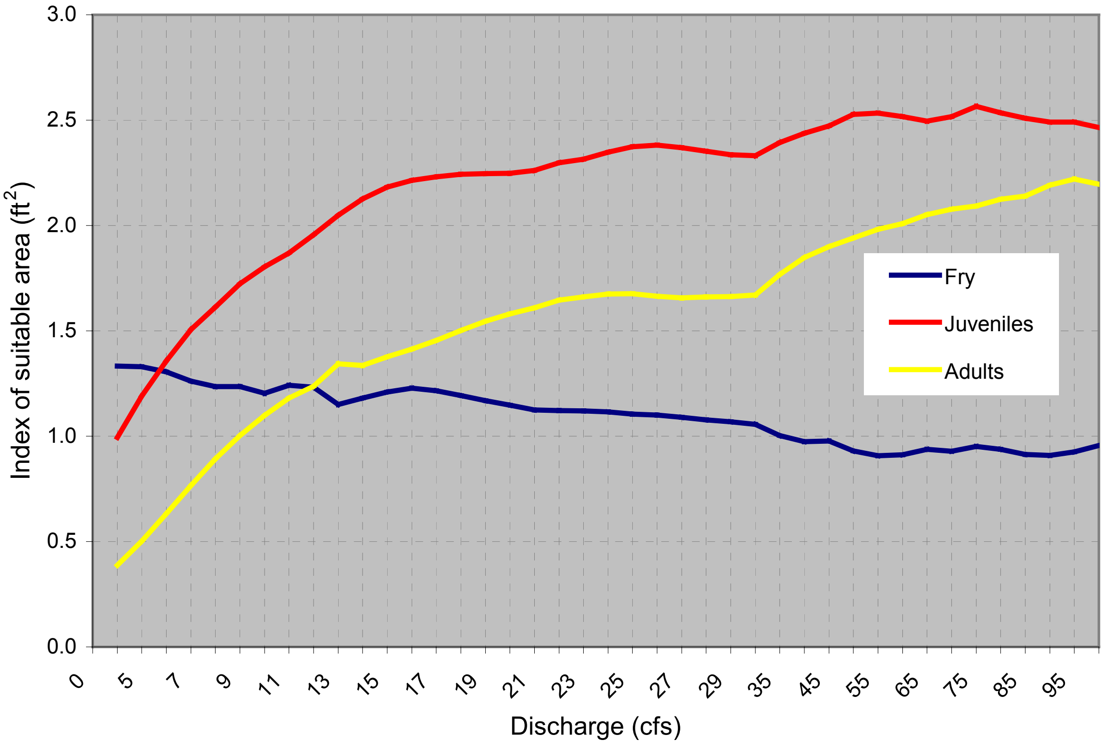

Figure 11. Yellowstone cutthroat trout weighted useable area for adult, juvenile, and fry life stages (ft^2 per foot of stream length). Each life stage curve is from a habitat-weighted average of 15 transects. Note x-axis values are scaled to show simulated flows.

Habitat Retention

Average depth, average velocity, and wetted perimeter across three riffle transects as a function of flow are listed in Table 9. At riffle 1, velocity is the first hydraulic criteria met as flow declines from its bankfull level to 7.8 cfs. Next, the wetted perimeter and depth criteria are met at a flow less than 4.0 cfs (lower flows could not be simulated reliably). Thus, two of three hydraulic criteria (wetted perimeter and mean depth) are retained by a flow of less than 4.0 cfs across riffle 1 (Table 9). In a similar fashion, 7.0 cfs retains two of three criteria on riffle 2 and 4.4 cfs is required to meet criteria on riffle 3. Therefore, the flow that retains two of three criteria for all of the studied riffles is 7.0 cfs. Based on the Habitat Retention model, a flow of 7.0 cfs is necessary year round to maintain trout survival, movement and invertebrate production.

Assessing 7.0 cfs in the context of adult and juvenile habitat, PHABSIM results show low suitability levels at lower flow levels and rapid gains in suitability at flow levels higher than 7.0 cfs (Figure 11). Under ice-free conditions, trout can move between pools at 7.0 cfs while greater flow levels would provide additional adult habitat. The HQI model results in the following section further define adult trout summer habitat needs. The need for natural winter flows, higher than 7.0 cfs, is discussed in a later section.

Table 9. Simulated hydraulic criteria for three Trout Creek riffles. Bold indicates that the hydraulic criterion was met. Bankfull is 250 cfs. Flows meeting 2 of 3 criteria for each riffle are shaded.

	Mean Velocity (ft/s)	Mean Depth (ft)	Wetted Perimeter (ft)	Discharge (cfs)
Riffle 1 – transect 1	7.54	1.43	24.4	250
	4.34	1.22	19.9	100
	2.86	0.96	18.9	50
	2.16	0.81	18.4	31
	1.20	0.56	16.6	11
	1.00	0.50	16.1	7.8
	0.71	0.38	15.2	4.0
	<0.71	**0.20**	**12.2**	**<4.0**
Riffle 2 – transect 5	6.68	1.13	34.9	250
	3.96	1.03	26.0	100
	2.64	0.93	21.6	50
	1.94	0.81	20.1	30
	1.07	0.60	17.9	11
	1.00	0.57	17.8	9.8
	0.83	0.50	**17.5**	**7.0**[a]
	0.62	0.39	17.0	4.0
	<0.62	**0.20**	<17.0	<4.0
Riffle 3 – transect 9	7.54	1.29	26.8	250
	4.48	0.99	23.5	100
	3.03	0.84	20.3	50
	2.28	0.72	19.0	30
	1.35	0.49	17.2	11
	1.00	0.45	13.8	6.0
	0.86	0.39	**13.4**	**4.4**
	0.82	0.38	13.3	4.0
	<0.82	**0.20**	<13.3	<4.0

[a] - Discharge at which 2 of 3 hydraulic criteria are met for all riffles.

Habitat Quality Index

A maximum water temperature of 65° F was recorded August 5, 2004. This temperature falls in the 55 - 65º F band for a rating of "4" under Binns (1982) and reflects optimal thermal conditions. A water sample for analysis of nitrates was not collected; however, nitrate levels are not expected to change as a function of flow and this attribute was held constant at an estimated rating value of "1". Eroding banks, at 13%, rated a "3". The substrate attribute was occularly estimated and rated a "1" due to low occurrence of aquatic vegetation. Percent cover ranged between 22% and 37% with the peak measured at 21 cfs. The cover rating changes from "2" to "1" when cover is less than 25% of the wetted channel. By linear interpolation, the cover rating declines to less than 25% at flows less than 13 cfs and greater than 30 cfs.

Peak Habitat Units occur between 18 and 20 cfs (Figure 12). Contributing to the peak are a combination of adequate base flow (CPSF rating peaks at 18 cfs), minimal annual stream flow variation

(ASFV rating peaks at 16 cfs), and greater than 25% cover (maximum rating occurs between 13 and 30 cfs). At flows greater than 20 cfs, higher velocities begin to limit the habitat quality.

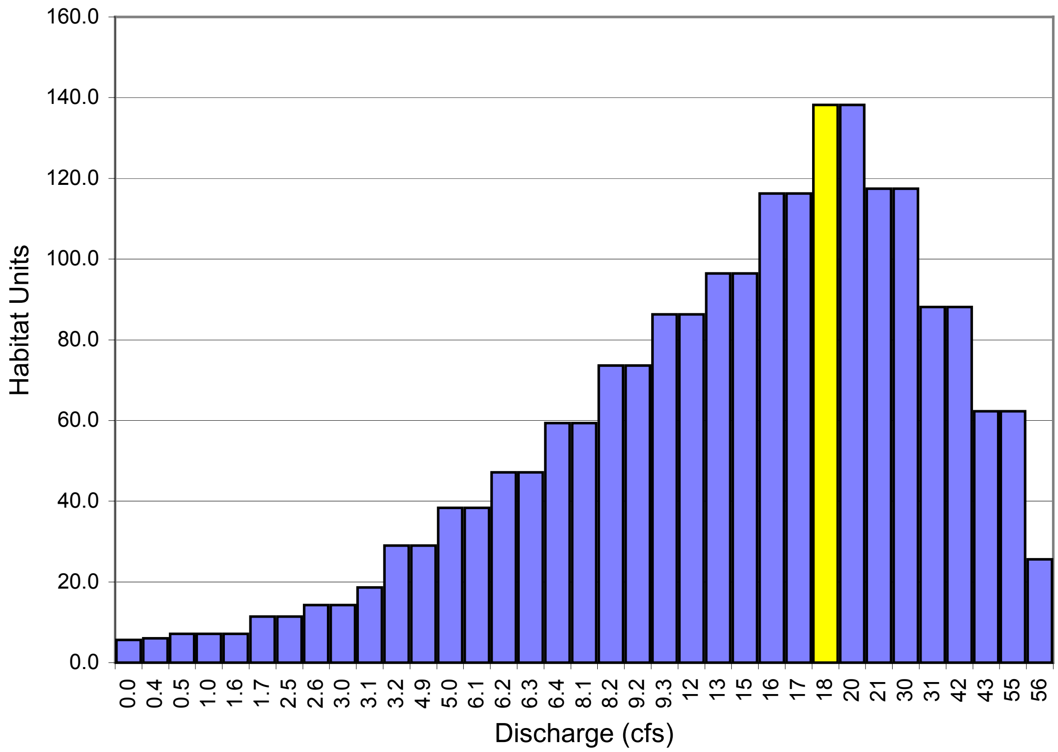

Figure 12. Habitat Quality Index for a range of flow levels. X-axis flows are scaled to show where changes in Habitat Units occur. The recommended flow is indicated by the light shaded bar.

Measured flows in the July through September period range from 9 to 21 cfs (Table 7). Estimated monthly streamflows that occur 50% of the time are: 74 cfs, 23 cfs, and 15 cfs for July, August and September (Table 8). The 23 cfs August value provides a reasonable estimate of normal late summer flow levels. At this flow, the stream provides 117 Habitat Units (Figure 12). The lowest flow that will maintain 117 Habitat Units is 18 cfs; therefore, the instream flow recommendation to maintain adult YSC habitat during the late summer period is 18 cfs. A flow of 16 cfs maintains 116 Habitat Units, nearly the same as maintained under existing conditions, but would not provide the habitat benefits that accrue at 18 cfs.

Winter Flows and Habitat

October, November, December, and March 20% monthly exceedance flows (Table 10) are recommended to maintain winter trout habitat. In January and February, the estimated 20% exceedance flow falls below the habitat retention flow. To maintain opportunities for fish passage and invertebrate production, the habitat retention flow of 7.0 cfs is recommended for January and February. This is only slightly more than the 20% exceedance flows for those months (6.9 and 6.4 cfs, respectively). HabiTech analyses indicate that 7 cfs does occur in January and February so this recommendation is feasible in the sense that such flow is available. From PHABSIM, adult and juvenile physical habitat drops sharply at low flows so 7.0 cfs provides better habitat than lower flows (Figure 12). PHABSIM results apply to ice-free conditions so extrapolation to winter is limited to ice-free areas and pools beneath a stable ice cover.

INSTREAM FLOW WATER RIGHT RECOMMENDATIONS

Trout Creek has important YSC habitat, a population of genetically pure trout in its headwaters and a mixed hybrid-pure population in the lower reaches. An instream flow filing will protect existing base flow conditions against unknown future consumptive and diversionary demands. About two miles of stream habitat will be directly protected and over 100 miles of headwaters will be indirectly protected if this instream flow application advances to permit status.

Trout Creek instream flow recommendations to maintain short-term Yellowstone cutthroat trout habitat are summarized in Table 10. Spring (April through June) instream flow recommendations to maintain Yellowstone cutthroat trout spawning habitat were developed using PHABSIM. Summer recommendations (July through September) to maintain Yellowstone cutthroat trout adult production were developed using the HQI model, while PHABSIM was used to ensure sufficient habitat for all life stages. Winter (October through March) flow recommendations were developed from a combination of Habitat Retention and natural winter flow estimates, defined as the 20% monthly exceedance. For January and February, estimated natural winter flow was less than the habitat retention flow. To maintain riffle hydraulic conditions, the habitat retention flow was recommended for these months.

Table 10. Trout Creek instream flow recommendations for short-term fishery maintenance.

Monthly Flow Recommendations (cfs)												
Oct	Nov	Dec	Jan	Feb	Mar	Apr*	May*	Jun*	Jul* 1 – 15	Jul 16 - 31	Aug	Sep
15	10	7.7	7.0	7.0	7.1	26	26	26	26	18	18	18

* Channel maintenance flow recommendations for the spring runoff period are defined in Appendix 1.

Channel maintenance flows to preserve the long-term habitat and ecological functions that support the existing fishery are described in Appendix 1. Flow recommendations apply to stream segments defined in Table 4.

Because data were collected from a range of habitats and simulated over a wide flow range, additional data collection under different flow conditions is not likely to significantly change these recommendations. New water storage facilities to provide the recommended amounts on a more regular basis than at present are not needed to maintain the existing fishery characteristics and would likely lead to significant changes to the existing habitat and fish community, some of which might not be desirable.

Based on HabiTech (2004) hydrology, the instream flow recommendations constitute a small portion of annual water yield in the Trout Creek basin, even in very dry years (Figure 13). In 1983 and 1992, the April instream flow recommendation was higher than estimated flows. In 1986, an example of a wet year, the spawning flow recommendation was present for 7 days in April. In years when runoff starts in April, the 26 cfs flow recommendation provides an opportunity for spawning. Also notable, the spawning flow recommendation is small (<20%) compared to peak flows, even in dry years (Figure 13). While normally higher runoff flows perform important channel functions that sustain the fishery over the long term (Appendix 1), physical area suitable for spawning is highest at relatively low flow levels around 26 cfs.

During the descending limb of the hydrograph, estimated flows through mid-July remain much higher than the spawning flow recommendations (Figure 13). In 1992, a dry year, August flow dropped below the 18 cfs recommended to maintain adult trout habitat. In the other example years, flow remains above 18 cfs until September. During the winter months, the recommended instream flow levels closely match natural winter flow levels (Figure 13).

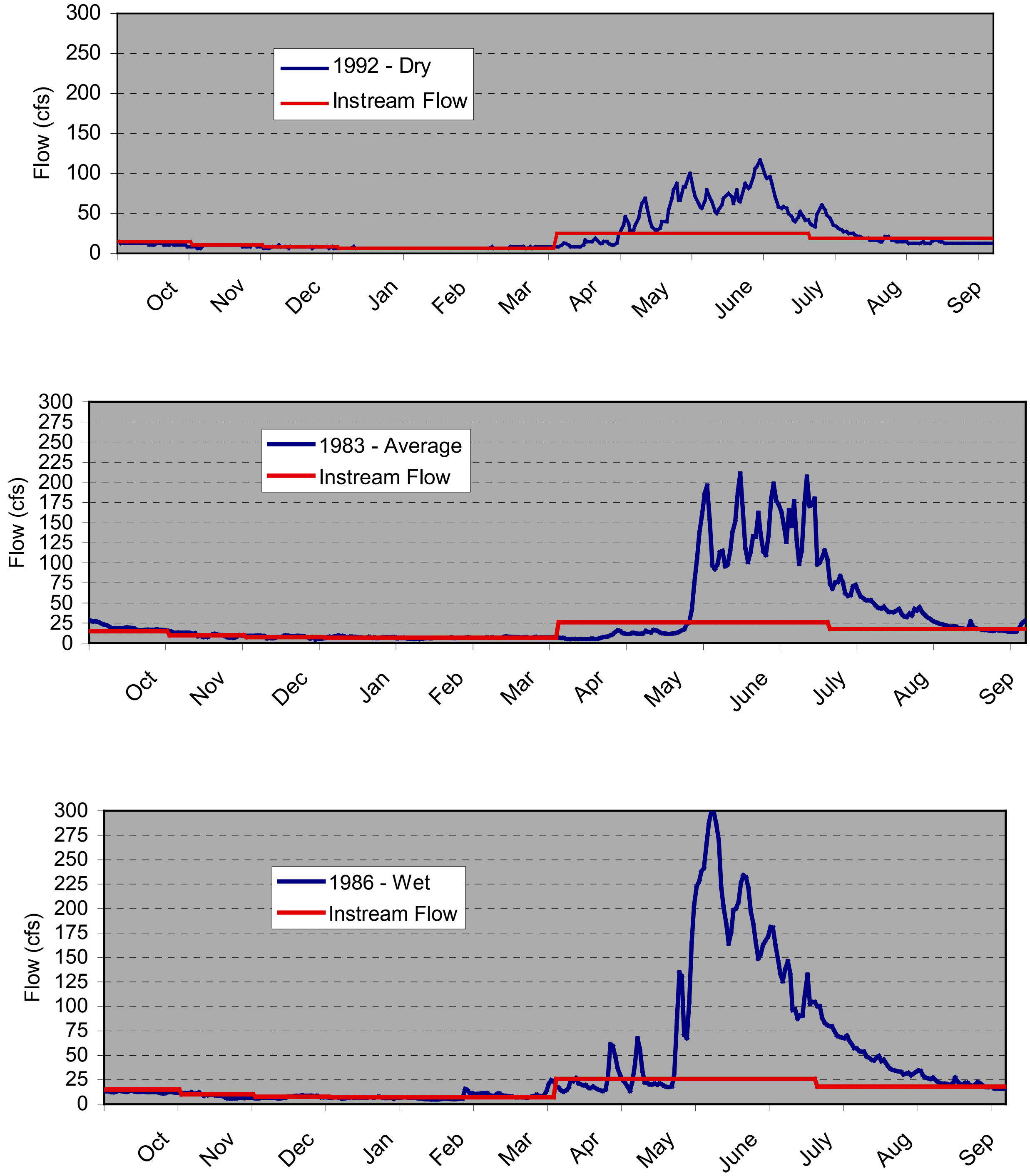

Figure 13. Trout Creek instream flow recommendations and hydrographs from water years in three exceedance classes: wet (0-10%), average (30-70%), and dry (90-100%).

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APPENDIX 1. CHANNEL MAINTENANCE FLOWS

The term "channel maintenance flows " refers to flows that maintain existing channel morphology, riparian vegetation and floodplain function (US Forest Service 1997, Schmidt and Potyondy 2004). The basis and approach used below for defining channel maintenance flows applies only to snowmelt-dominated gravel and cobble-bed (alluvial) streams. By definition, these are streams whose beds are dominated by loose material with median sizes larger than 2 mm and with a pavement or armor layer of coarser materials overlaying the channel bed. In these streams, bedload transport processes determine the size and shape of the channel and the character of habitat for aquatic organisms (Andrews 1984, Hill et al. 1991, Leopold 1994).

A flow regime that provides channel maintenance results in stream channels that are in approximate sediment equilibrium where sediment export equals sediment import on average over a period of years (Leopold 1994, Carling 1995, Schmidt and Potyondy 2004). Thus, stream channel characteristics over space and time are a function of sediment input and flow (US Forest Service 1997). When sediment-moving flows are removed or reduced over a period of years, some gravel-bed channels respond by reducing their width and depth, rate of lateral migration, stream-bed elevation, bed material composition, stream side vegetation and water-carrying capacity.

Maintenance of channel features and floodplain function cannot be obtained by a single threshold flow (Kuhnle et al. 1999). Rather, a dynamic hydrograph within and between years is needed (Gordon 1995; Trush and McBain 2000, Schmidt and Potyondy 2004). High flows are needed in some years to scour the stream channel, prevent encroachment of stream banks and deposit sediments to maintain a dynamic alternate bar morphology and successionally diverse riparian community. Low flow years are as valuable as high flow years on some streams to allow establishment of riparian seedlings on bars deposited in immediately preceding wet years (Trush and McBain 2000). The natural interaction of high and low flow years maintains riparian development and aquatic habitat by preventing annual scour that might occur from continuous high flow (allowing some riparian development) while at the same time preventing encroachment by riparian vegetation that could occur if flows were artificially reduced at all times.

Channel maintenance flows must be sufficient to move the entire volume and all sizes of material supplied to the channel from the watershed over a long-term period (Carling 1995, Schmidt and Potyondy 2004). A range of flows, under the dynamic hydrograph paradigm, provides this function. Infrequent high flows move large bed elements while the majority of the total volume of material is moved by more frequent but lower flows (Wolman and Miller 1960, Leopold 1994). In streams with a wide range of sediment sizes on the channel boundary, a range of flows may best represent the dominant discharge because different flow velocities are needed to mobilize different sizes of bed load and sediment. Kuhnle et al. (1999) note "A system designed with one steady flow to transport the supplied mass of sediment would in all likelihood become unstable as the channel aggraded and could no longer convey the sediment and water supplied to it. A system designed with one steady flow to transport the supplied sediment size distribution would in all likelihood become unstable as the bed degraded and caused instability of the banks."

A total bedload transport curve (Figure 1-1) shows the amount of bedload sediment moved by stream discharge over the long-term as a product of flow frequency and bedload transport rate. This schematic shows that any artificial limit on peak flow prevents movement of the entire bedload through a stream over time and would result in gradual bedload accumulation. The net effect would be an alteration of existing channel forming processes and habitat (Bohn and King 2001). For this reason, the 25-year peak flow is the minimum needed to maintain existing channel form.

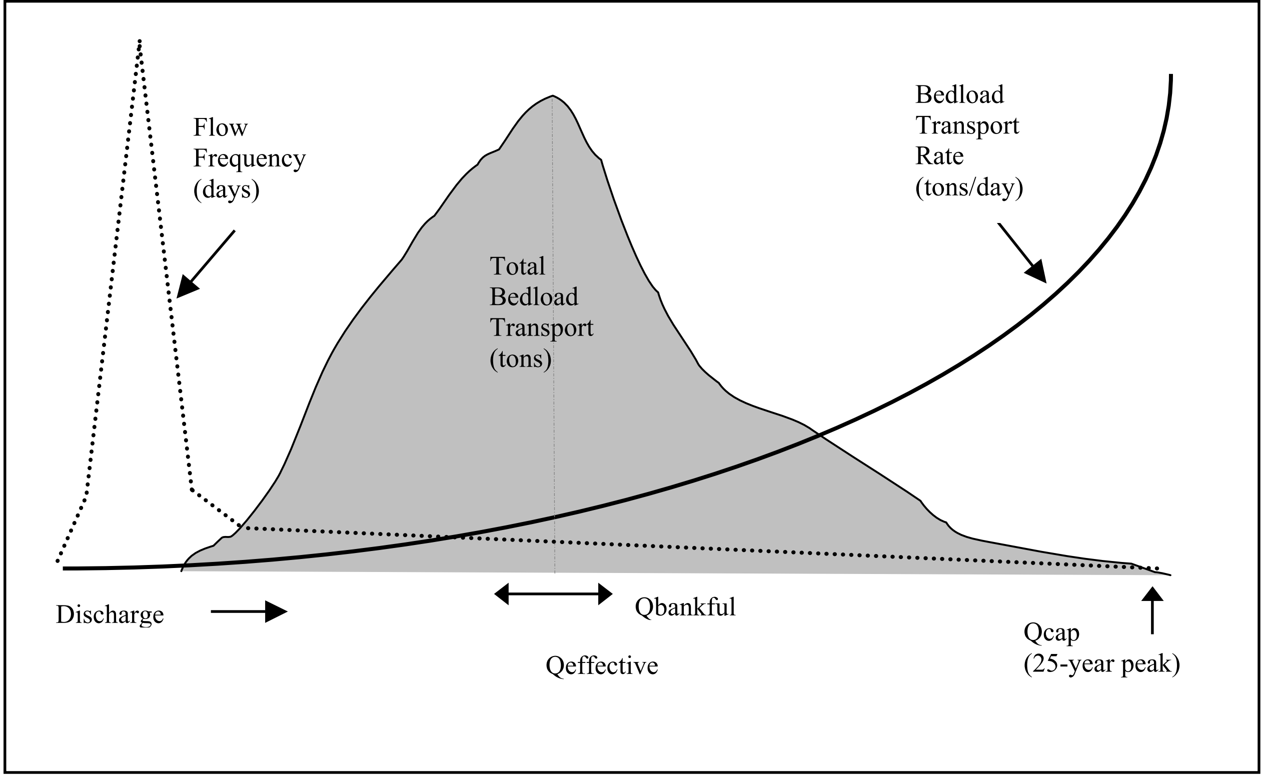

Figure 1-1. Total bedload transport as a function of bedload transport rate and flow frequency (adapted from Schmidt and Potyondy 2004).

The initiation of particle transport begins at flows somewhat greater than average annual flows but lower than bankfull flows (Schmidt and Potyondy 2004). Ryan (1996) and Emmett (1975) found the flows that generally initiated transport were between 0.3 and 0.5 of bankfull flow. Movement of coarser particles begins at flows of about 0.5 to 0.8 of bankfull (Carling 1995, Leopold 1994). Schmidt and Potyondy (2004) discuss phases of bedload movement and suggest that a flow trigger of 80% of the 1.5-year discharge "provides a good first approximation for general application" in defining flows needed to maintain channels. They suggest that although lower flows will initiate fine sediment movement, "delaying the initiation point of the channel maintenance hydrograph (to $0.8 * Q_b$), is desirable because it minimizes the long-term volume of water needed for channel maintenance."

Based on these principles, the following model was developed by Dr. Luna Leopold and is used in this report:

$$\text{Q Recommendation} = Q_f + \{(Q_s - Q_f) * [(Q_s - Q_m) / (Q_b - Q_m)]^{0.1}\}$$

Where: Q_s = actual stream flow
Q_f = fish flow
Q_m = substrate mobilization flow = $0.8 * Q_b$
Q_b = bankfull flow

The model is identical to the one presented in Gordon (1995) and U.S. Forest Service (1994) with one variation. The model presented in those documents used the average annual flow as the flow at which substrate movement begins. This term was re-defined here as the substrate mobilization flow (Q_m) and assigned a value of 0.8 times bankfull flow based on the report by Schmidt and Potyondy (2004). Setting Q_m at a higher flow level leaves more water available for other uses and thus better meets the statutory standard of "minimum needed".

Application of the equation results in incrementally higher percentages of flow applied toward channel maintenance as flow approaches bankfull (Figure 1-2). Flows less than half of bankfull are available for other uses unless needed for direct fish habitat. At flows greater than bankfull but less than the 25-year flow level, the channel maintenance instream flow recommendation is equal to the actual flow. Flows greater that the 25-year recurrence flow are not necessary for channel maintenance and are available for other uses.

Under the dynamic hydrograph approach, the volume of water required for channel maintenance is variable from year to year. During low flow years, less water is required for channel maintenance because flows may not reach the defined channel maintenance level. In those years, most water in excess of base fish flows is available for other uses. The majority of flow for channel maintenance occurs during wet years. One benefit of a dynamic hydrograph quantification approach is that the recommended flow is needed only when it is available in the channel and does not assert a claim for water that is not there as often happens with threshold approaches.

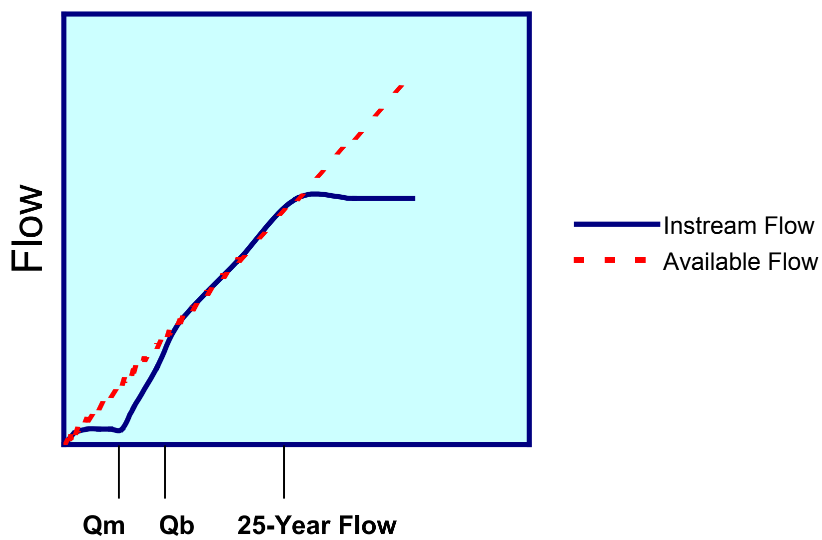

Figure 1-2. General function of a dynamic hydrograph instream flow for fishery maintenance. Q_m is substrate mobilization flow and Q_b is bankfull flow.

The Leopold equation yields a continuous range of instream flow recommendations at flows between the sediment mobilization flow and bankfull for each cubic foot per second increase in flow (Figure 1-2). This manner of flow regulation is complex and could prove burdensome to water managers. To facilitate flow administration while still ensuring reasonable flows for channel maintenance, we modified this aspect of the approach to claim instream flows for four evenly partitioned blocks or increments of flow between the sediment mobilization flow and bankfull (see Table 1-1).

Like all properly functioning rivers, the Trout Creek instream flow segment has a hydraulically connected watershed, floodplain, riparian zone and stream channel. Bankfull and overbank flow are essential hydrologic characteristics for maintaining the habitat in and along these river segments in their existing dynamic form. These high flows flush sediments from the gravels and maintain channel form (i.e., depth, width, and pool and riffle configuration) by periodically scouring encroaching vegetation. Overbank flow maintains recruitment of riparian vegetation, encourages lateral movement of the channel, and recharges ground water tables. Instream flows that maintain the connectivity of these processes over time and space are needed to maintain the existing fishery (Annear et al. 2004).

Applying the Leopold equation and approach yielded the channel maintenance instream flow recommendations in Table 1-1. The base or fish flow used in the analysis was the 26 cfs spawning flow. For naturally available flow levels less than the spawning flow, the channel maintenance instream flow recommendation is equal to natural flow. The spawning flow level is considerably less than the substrate mobilization flow (200 cfs). For the flow range between the spawning flow and the substrate mobilization flow, the channel maintenance flow recommendation is equal to the spawning flow (Table 1-1). When naturally available flows range from the substrate mobilization flow to the bankfull flow level, application of the Leopold formula results in incrementally greater amounts of water applied toward instream flow (Table 1-1). At flows between bankfull and the 25-year flood flow, all of the streamflow is needed to perform channel maintenance functions. At flows greater than the 25-year flood flow, only the 25-year flood flow is needed for channel maintenance because this flow level will have moved the necessary amount of bed load materials and reconnected the channel with the floodplain (Figure 1-2).

Table 1-1. Channel maintenance instream flow recommendations (shaded columns) to maintain existing channel forming processes and long-term aquatic habitat characteristics in the Trout Creek instream flow segment. Recommendations apply to the run-off period from April 1 through July 15th.

Flow Level Description	Trout Creek Flow (cfs)	
	Available	Channel
<Spawning Flow*	<26	<26
Spawning Flow	26	26
<Substrate Mobilization	27-199	26
Substrate Mobilization	200	26
Mobilization to Bankfull	201-212	144
Mobilization to Bankfull	213-224	189
Mobilization to Bankfull	225-237	212
Mobilization to Bankfull	238-249	232
Bankfull	250	250
Bankfull to 25-Year Flood[#]	251-554	251-554
25-Year Flood	555	555
> 25-Year Flood	≥ 555	555

*At stream flows less than the spawning flow, the flow recommendation is all available flow.
Between bankfull and the 25-year flow, the flow recommendation is all available flow.

Figure 1-2 shows examples of channel maintenance flow recommendations implemented in a randomly selected average, moderately wet and wet year. Dry or moderately dry years are not shown because during most of these years flows would not exceed the 200 cfs substrate mobilization threshold to initiate channel maintenance flows. In the representative average year, 1983, flow exceeded 200 cfs on a single day (211 cfs) yielding a flow recommendation of 144 cfs for that day (Table 1-1). In moderately wet 1999, flow exceeded 200 cfs for nine days in June and one day in July. Flow exceeded the 250 cfs bankfull level on four of these ten days, resulting in a flow recommendation equal to available flow (Table 1-1). In a wet year as in 1986, channel maintenance flow recommendations would apply for 19 days in May and June (Figure 1-2).

If water storage were developed (though it is not recommended for this cutthroat trout fishery) it would be necessary to further specify the rate at which releases could be increased or decreased to the channel maintenance or spawning levels. The sharp flow increases and decreases evident in Figure 1-2 (e.g. 26 cfs to 212 cfs in one day) would cause habitat loss through excessive scour and potential trout mortality due to stranding. More gradual changes akin to a natural hydrograph would be recommended. In that case, the Index of Hydrologic Alteration (IHA; Richter et al. 1996) could provide a valuable reference. Daily increases and decreases during runoff measured at the North Fork Shoshone gages could serve as guide for developing such ramping rate recommendations using the IHA.

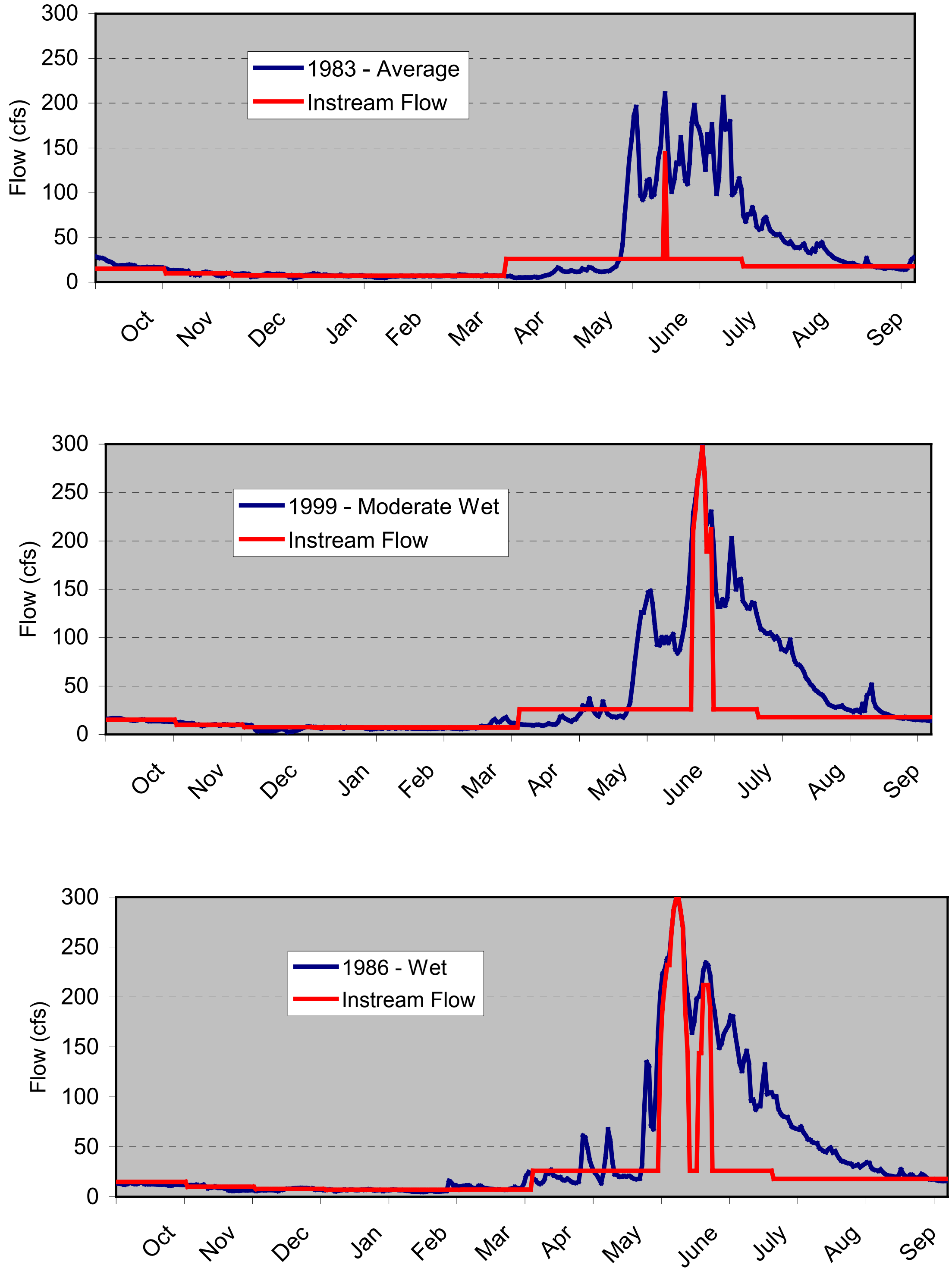

Figure 1-2. Trout Creek channel maintenance flow recommendations and hydrographs in an average (1983), moderately wet (1999) and wet (1986) water year.

APPENDIX 2. HABITAT SUITABILITY CRITERIA

Substrate codes are 1=vegetation, 2=mud, 3=silt, 4=sand, 5=gravel, 6=cobble, 7=boulder, 8=bedrock. Decimals indicate the percent of the next higher class code (e.g. 4.4 = 60% sand, 40% gravel). Maximum suitability is scaled to "1". See text for details on curve development.

Velocity (ft/s)	Suitability	Depth (ft)	Suitability	Substrate Code	Suitability
Spawning (Thurow and King 1994)					
0.00	0.00	0.00	0.00	4.0	0.00
0.59	0.00	0.32	0.00	4.1	0.10
0.69	0.10	0.34	0.10	4.2	0.20
0.94	0.20	0.37	0.20	4.3	0.50
1.10	0.50	0.45	0.50	4.4	1.00
1.12	1.00	0.52	1.00	5.6	1.00
1.72	1.00	0.82	1.00	5.7	0.50
1.82	0.50	0.97	0.50	5.8	0.20
2.06	0.20	1.27	0.20	5.9	0.10
2.26	0.10	1.58	0.10	6.0	0.00
2.31	0.00	1.75	0.00		
Adults (Dey, Trout Creek 2004)					
0.00	0.20	0.00	0.00	1-8	1.00
0.29	0.20	0.70	0.00		
0.33	0.50	0.82	0.10		
0.36	1.00	0.89	0.20		
1.91	1.00	1.02	0.50		
2.18	0.50	1.15	1.00		
2.47	0.20	1.60	1.00		
2.79	0.10	1.70	0.50		
3.11	0.10	1.81	0.20		
3.12	0.00	2.00+	0.20		
Juvenile (Dey, Trout Creek 2004)					
0.00	0.20	0.00	0.00	1-8	1.00
0.15	0.20	0.40	0.00		
0.27	0.50	0.55	0.10		
0.38	1.00	0.77	0.20		
1.65	1.00	0.92	0.50		
1.79	0.50	1.00	1.00		
2.31	0.20	1.50	1.00		
3.12	0.10	1.63	0.5		
3.37	0.00	1.78	0.20		
		2.00+	0.20		
Fry					
0.00	0.60	0.00	0.00	1-8	1.00
0.03	1.00	0.03	0.10		
0.07	0.90	0.07	0.20		
0.10	0.60	0.10	0.20		
0.13	0.60	0.13	0.40		
0.16	0.50	0.16	0.60		
0.20	0.30	0.20	0.60		
0.23	0.30	0.23	0.70		
0.27	0.20	0.26	0.80		
0.30	0.10	0.30	0.90		
0.52	0.10	0.36	0.90		
0.56	0.00	0.39+	1.00		

APPENDIX 3. ROSGEN LEVEL II MEASUREMENTS

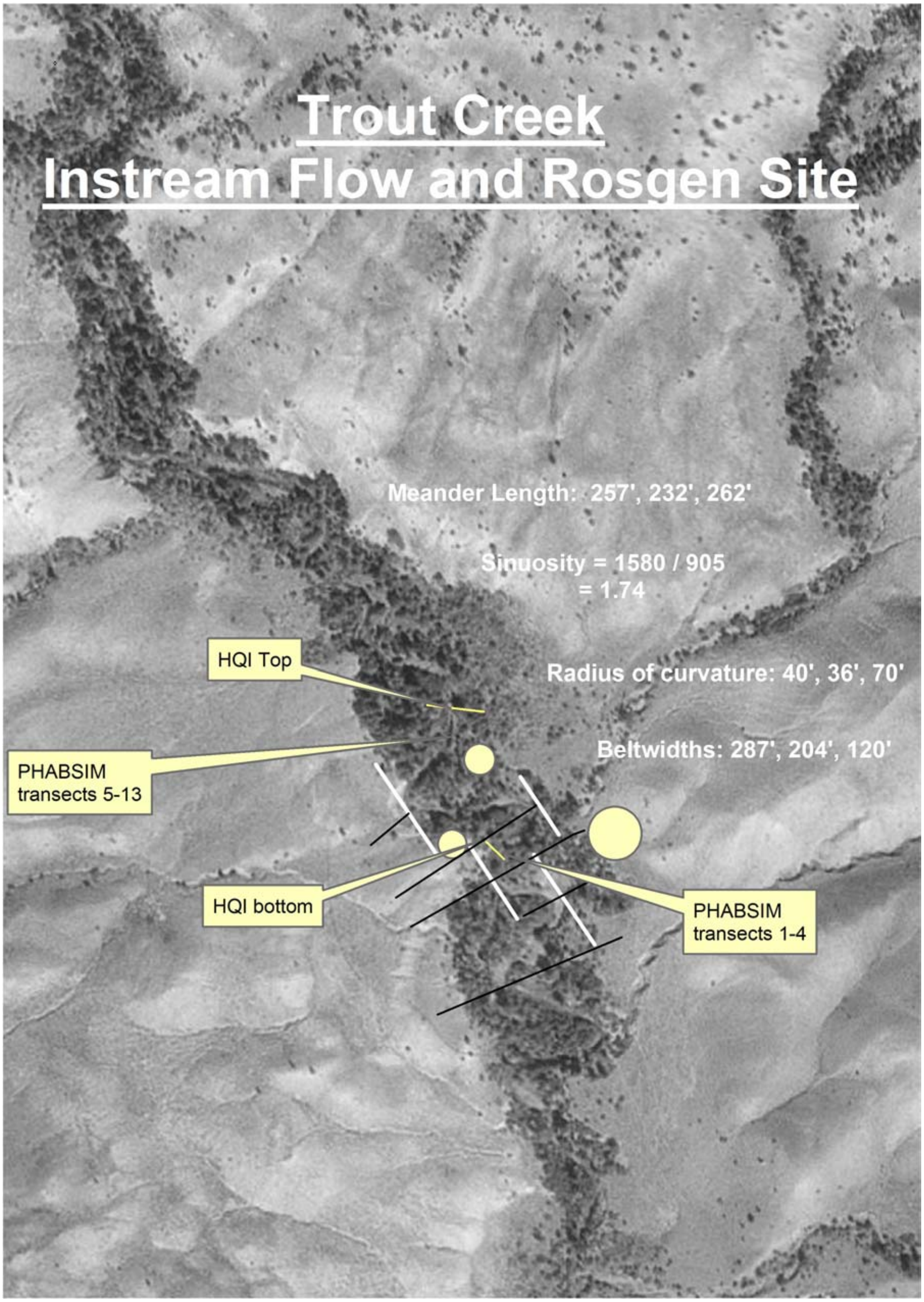

Figure 3-1. Digital ortho photo of Trout Creek and channel plan form measurements in ArcMap.

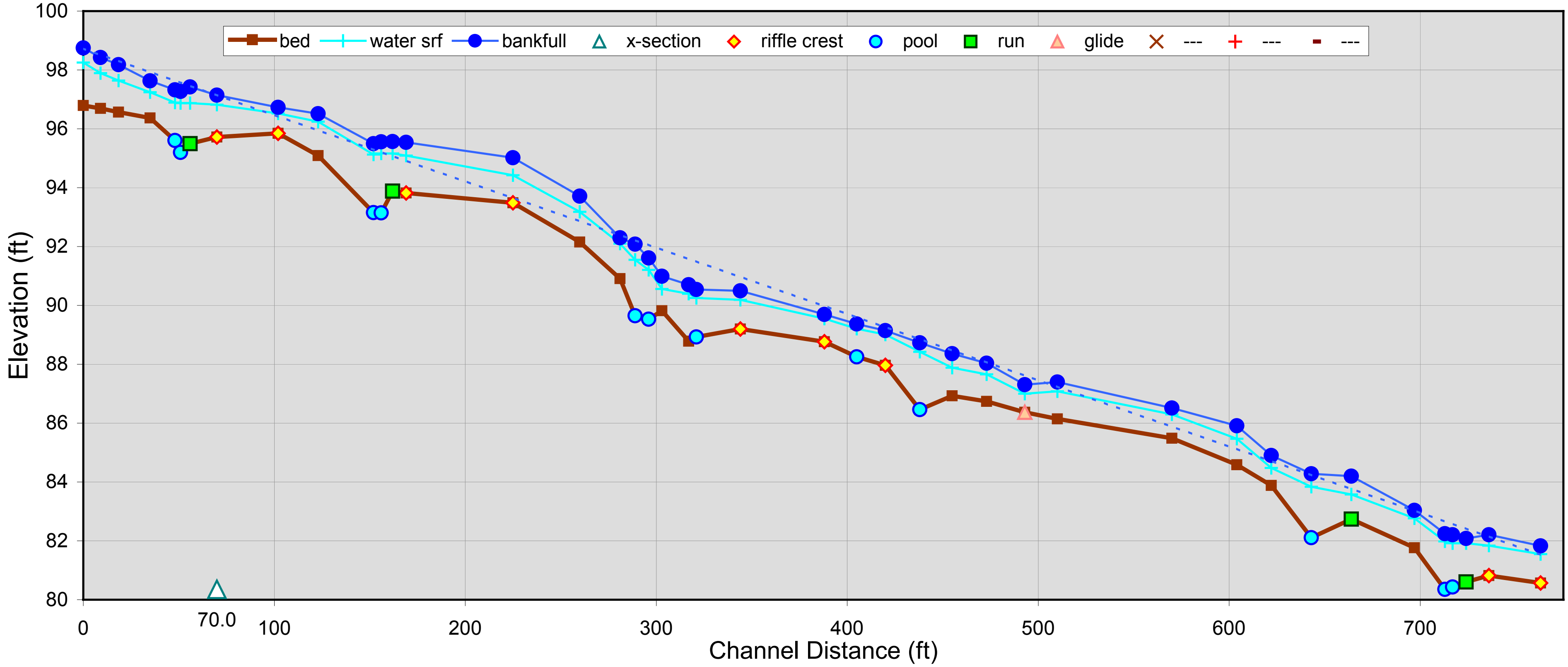

Figure 3-2. Longitudinal profile through instream flow study site and HQI reach. Square "bed" symbols indicate rapids. Marker at 70 feet indicates riffle transect number 9 where cross section survey was conducted. Transects 5 – 8 were at stations 152 through 169 feet and transects 1-4 were at stations 713 – 763 feet.

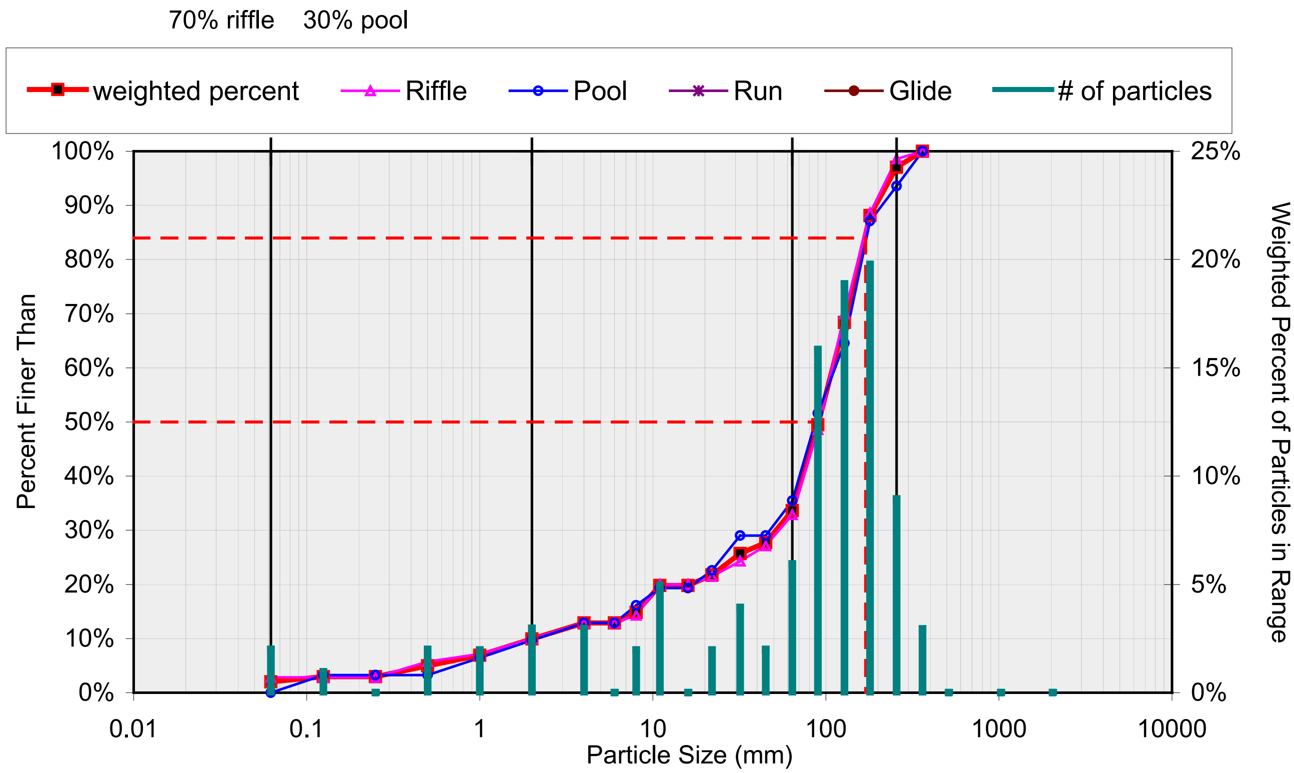

Figure 3-3. Pebble count particle distribution.